Literature Review
for the
Development of a Socio-Economic Impacts Assessment Procedure
to be applied to the flooding of
Qianliang Hu Detention Basin, Hunan Province, China

Abstract

A literature review is undertaken for the development of a socio-economic impacts assessment procedure for Qianliang Hu flood detention basin in Central China. This basin is one of 40 basins that might be deliberately flooded to reduce flood water levels within the middle reach of the Yangtze River.

The review considers the elements of flood damage, environmental conditions that contribute to that damage and different scales of analysis. Literature pertaining to both the tangible and intangible costs of flooding are examined with particular reference to the use of loss rates in China as derived by and used by several authors. The paper then describes how these might be applied to the context of flooding detention basins.

The social impacts of flooding are discussed including mortality estimation methods and how these might be combined to derive social impact indices for each detention basin.
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INTRODUCTION

The purpose of this paper is to examine recent trends in flood impact assessments and establish a framework for the development of a flood damage estimation procedure (FDEP) for the Qianliang Hu detention basin. Additional literature will be examined to widen the scope of the flood damage estimation procedure (FDEP) to a socio-economic impact assessment process that can be used in a much wider project involving some 40 detention basins in the middle reach of the Yangtze River.¹

Data provided by the Changjiang Water Resources Commission for Qianliang Hu basin is being examined and compared to suggestions and conclusions made in the literature review to develop a suitable framework for the impact assessment procedures. Results of the procedure will be compared with actual statistics and the procedure then applied to the much larger Jingjiang detention basin. Finally verification of the procedure will be made by its application to two smaller basins subject to the availability of data. This development and verification work will be reported separately.

This review is structured in the following manner. After presenting background information relevant to flood damage in China and the relevance of Qianliang Hu detention basin, the overall design of a possible FDEP is examined with respect to scale. The review then examines elements of flood damage and provides more information on tangible and intangible losses. Types of flood damage estimation procedures currently used elsewhere are reviewed and contrasted with those currently practiced in China. Also examined are social impact assessment measures and how these might be incorporated with tangible losses into the presentation of socio-economic impacts associated with the deliberate flooding of detention basins. Finally the review examines the totality of the information presented herein and how that information might be combined.

¹ Author’s note: Much of the literature examined in this review has been written and translated by those who do not have English as their first language. This can pose some difficulties when trying to interpret the message the author is intending to convey particularly where the paper has been translated or written in the author’s second (or third language).
BACKGROUND

Flooding in China is a serious problem with annual flood damage during the 1990s accounting for between 1% and 4% of National GDP in individual years, an amount 10 to 20 times that experienced in Japan and the United States (Cheng 2002). One third of the cultivated land, half the population and two thirds of the assets suffer flood damage (Wang and Xiang 2002). One of the major areas of risk is the Yangtze River basin in Central China where over 77 million people live within polders.

In 1954 a massive flood in the Yangtze River basin is reported to have killed between 30,000 and 40,000 people. Since then six dams have been constructed, two are under construction (including the Three Gorges Dam with 18,200 MW of installed generating capacity) and 40 detention ponds have been completed. In 1998 a major flood of the Yangtze River occurred over a three month period and caused a major disruption to economic activity. During this period about 3200 lives were lost. The Chinese Government immediately commenced several hundred flood mitigation projects throughout the country for an expected benefit cost ratio of over 6; and are attempting to raise development flood standards to 1% AEP for metropolitan and critical infrastructure, to 2% AEP for other prime development areas and to 10% annual exceedance probability (AEP) for farmlands (Zhang Y. 2002).

Many countries have become involved in partnership arrangements including Australia whose international aid agency AusAID sponsored the Yangtze River Flood Control Management Project (YRFCMP) currently being undertaken by the Governments of the Peoples Republic of China and Australia. One of the components of this project is the development of a Decision Support System (DSS). This DSS is intended to present information on the current flood situation in the upper and middle reaches of the Yangtze River; the status of flood control facilities; develop and present a series of flood management and control options; and a decision makers consultation system through a web-based Visual Display System (VDS), (SAGRIC Sept 2002a).

One sub-component is the DSS is an Options Analysis System (OAS). This system will, when developed, present a series of flood management options together with the consequences of enacting those options. Activities to be developed as part of the project include the

1. development of a flood classification (description) system;
2. provide answers to questions that flood managers may ask during a flood emergency;
3. presentation of flood management options;
4. development of a flood damage estimation procedure;
5. development of socio-economic impacts indices for flooded detention basins; and
6. recommendations as to which flood control option(s) might be used

Water levels in the Yangtze River high enough to put major communities and infrastructure at risk can be alleviated to some extent by diverting floodwaters into one or more of 40 detention basins in the middle reach of the Yangtze River. Which basins are used depends on the sources of arriving floodwaters, the hydraulic set up within the system, the magnitude of the total flood situation and flood forecasts. Decisions to divert floodwater are not taken
lightly as the diversion basins often have their own significant populations, high agricultural value and other activities of economic significance. At least 350,000 people would have to be evacuated from the Jingjiang detention basin and at least 120,000 form Qianliang Hu detention basin.

The Implementation Plan (SAGRIC Sept 2002b) proposes to develop a flood damage estimation procedure for the Qianliang Hu detention basin in Hunan Province at the northern and downstream extent of the Dongting Lakes system. The importance of this system for the storage of Yangtze River floodwaters is outlined in Zheng et al (2002). Qianliang Hu has a flood storage capacity of 2.22 billion cubic metres ($\text{m}^3$), an area of 420 $\text{km}^2$ and is home to 171,000 people. It has about 220 $\text{km}^2$ under cultivation. In the 1996 flood, two of the five basins that comprise the Qianliang Hu detention basin set experienced a loss of 11,000 houses, 31 schools, 159 km of power lines and a damage bill of 1.9 billion RMB (personal communication with officers of CWRC).

The present method of diverting floodwaters is to either operate control gates or if they do not exist, deliberately breach dykes surrounding the polder by explosives and allowing erosion to expand the breach. Inundation of a basin can be rapid. Floodwaters can remain high for several weeks (as in the August 2002 flood) to months (as in the June to September 1998 flood), and result in total loss of agricultural product. Buildings near a breach may suffer structural as well as water damage and may need to be demolished during clean up operations.

Literature will influence the final design of the flood damage estimation procedure, its scale of application and how the various elements can be incorporated not only to produce a tangible damage model, but also present the social impacts of flooding. It is also likely that the procedure developed for Qianliang Hu and other detention basins will be used to justify further funding of flood mitigation schemes. It may also be modified to develop flood damage impact assessments for the high priority protection areas adjacent to the basin.
ELEMENTS OF FLOOD DAMAGE MODEL DESIGN

**Element of Disaster Costs**

Flood damage means different things to different people, and can refer to:
- replacement cost when damage items are discarded;
- repair cost when damaged items are repaired; and
- loss in value when damaged items are neither discarded or repaired, (Blong p175 within Smith and Handmer 2002).

Blong refers to the United States Army Corps of Engineers, “Risk based analysis for flood damage reduction studies”, Engineer Manual 1110-2-1619, that outlines a number of factors that contribute to flood damage:
- Over floor flooding depth;
- Velocity;
- Duration of inundation;
- Sediment;
- Building materials;
- Building age, which can indicate the type of materials and building condition;
- Content location (e.g. shoes being placed on the floor rather than on a shelf); and
- Warning time.

Smith in Chapter 4 also suggests that other factors that contribute to residential flood damage are:
- Flood height range;
- Lateral extent of flooding, (narrow floodplains often produce higher velocities while wide floodplains increase travel times and reduce effective mitigation time);
- Potential for building failure; and
- Failure of structural mitigation measures.

How relevant these are for application to the flood damage estimation procedures that will be developed will depend on the flood conditions and types of assets that will be damaged. Blong’s chapter discusses in some detail building and contents losses within Australia and compares them with earlier and possibly dated (Blong) work done in the United States. (This work was also referenced by Chen (2002) when discussing contents loss ratios).

The loss rates and graphs contained in this chapter (of Smith and Handmer) are relevant to Australian conditions only and can not be directly translated to Chinese conditions. One notable absence in the Australian data is an analysis of flood warning time that would provide a basis for further categorisation of contents damage. In the background reading for this review very little information has been found on the impact of warning time and probably more importantly, “effective mitigation time” which could be defined as being the period from when residents begin to take actions to reduce loss until inundation.

Water Studies (1997) refer to the importance of warning time in reducing contents damage and suggest losses can be reduced by 30% or more depending on the circumstances at the time.
Berry (in Chapter 14 of Smith and Handmer) reports that “people are usually poorly prepared for flood damage events and characteristically respond late and inadequately to flood warnings”, (p233). She provides a number of reasons but significantly suggests an inability of residents to access reliable information, (p241).

The figure below (copied from BTE 2001 p.63) shows the various elements of the costs of a disaster.

This modern Australian approach to the theoretical framework for the costs of a disaster is based on earlier Australian practice and has commonality with many other countries. Mitchell and Thomas (page 77) note that the compilation of loss data is fraught with difficulties. They find it significant that only a portion of the true costs are reported in damage statistics and the hidden costs are not reported. They include indirect costs, beneficial uses of hazardous areas that might ameliorate losses and intangible losses they suggest are rarely included in the official disaster costs. These statements indicate that unless some attempts is made to make reasonable estimation of indirect and intangible consequences, future potential damage estimates will be low and could lead to incorrect flood management decisions.

The costs of a disaster are the sum of the tangible and intangible costs, however in the diagram above, the word tangible is not used but both direct costs and indirect cost themes are expanded.

UNESCAP (1997) catagorise flood losses in much the same way as do BTE but suggest an additional sub-classification of recurrent and non-recurrent losses. Non-recurrent losses are those which will not occur when a future event takes place. They given the example of damaged bridges that are replaced with bridges that might be constructed at a higher level.
and state that in general only recurring losses need to be considered. This process would
understate the amount of direct damage because the residual life of the bridge before the
flood damage occurs would be ignored and the alternative opportunity cost of constructing a
newer, higher bridge ahead of schedule.

**Environmental Conditions Contributing to Flood Damage**
The conditions usually considered as contributing to the magnitude of flood damage include
causes of flooding (dam failure, dyke breach or riverine flooding), rate of rise of floodwater,
depth and duration of flooding. Many of these are mutually dependent. However the flood
damage estimation procedure is to be developed for a specific need: *i.e.* to determine the
damage caused by the flooding of a detention basin. How it is to be formulated will depend
on the causes of flooding, *viz.:

- Local flooding within the basin caused by heavy rain in which case the depth of
  flooding will be comparatively shallow.
- Failure of a dyke before it overtops (*e.g.* sand boil, or piping leading to embankment
  failure). Unless emergency efforts can repair the failure, final flood levels are likely
to be the same as the adjoining waterway and flood depths within the basins can be in
the order of six metres of more.
- Deliberate flooding of a basin as a means to reduce or control flood levels in the
  adjacent riparian system. For many basins, dykes will be deliberately breached to
  maximise the flow rate from the river. Final flood levels (and hence depths) within
  the basin will correspond to flood levels in the adjoining river.
- Overtopping of dykes thereby allowing partial to complete flooding of the polder or
  detention basin.

The flood damage estimation procedure may need to be able to accommodate a range of
damage types based on flood depth, rather than for just complete filling and perhaps impact
forces. To what extent this is applied will depend on the data that becomes available and
environmental conditions.

Losses of moveable items will depend on the time available for owners to move property and
stock and for flood proofing fixed assets. The effect of the duration of flooding on structures
will depend on the durability of materials used in construction. Farming losses can be
assumed to be a maximum once the duration of flooding exceeds one to two weeks
depending on the type of type of activity. Although some animals will be able to swim to
higher ground they could be lost to their owners. It must be presumed that fish in submerged
fish ponds will escape.

Aspects that will influence the magnitude of flood impacts include:
- Land characteristics: elevation, surface roughness, locality of development and
  location of refuge mounds;
- Land use distribution: relating to spatial distribution of features with respect to the
  level of the feature, their proximity to the road network or places of refuge and the
  heights of features.

Loss rates are accepted to be the ratio of actual losses to potential loss and depend on the
warning time, the experience of flood prone residents to flooding, the number of assets that
have been temporarily relocated out of danger, and for agriculture, the stage of the growing
season, (pers. comm. CWRC/Provincial personnel).
Stage–loss rate curves have been developed for residential and commercial properties based on value class, floor area and depth of flooding by several agencies. Adapting these for Qianliang Hu detention basin will depend on the availability of data within the basin itself. For example tabulations of the cost of repairing flood inundated roads will hopefully include road classification (major, minor, unsealed), initial repairs, cost of accelerated depreciation and bridge repairs. This can only be done with sufficient data.

In the Yangtze River basin (where up to three crops a year are sometimes possible), flooding, draining and recovery after a flood can take up to five months and mean the additional loss of another growing season.

**Matters of Scale**

Flood damage modelling will be heavily dependent on the availability of data and the scale at which the data is produced. The scale may vary from small cell type models that typically have only one land use type per cell, to medium scale models that consider distinct geographic, social or functional units (such as detention basins). Large scale or macro type models that whilst they may be considered as aggregates of medium scale models are treated at whole of river basin or tributary catchment area level.

It is thought that although the flood damage estimation procedure will be developed as a medium scale procedure it has to be verified by small scale modelling and checked against information gained from macro techniques. Accordingly this review will examine literature for all three scales of flood damage modelling. This is confirmed by Wang and Xiang’s (2002) research that’s shows flood damage assessment models have to be at different scales depending on the availability of flood damage information and suggest that fine scale, medium scale and macro scale models need to be developed.

The following summaries some recent literature relevant to China and in some cases to the Yangtze River basin in particular.

**Fine scale**

Wang and Xiang define fine scale by the use of 1:10,000 GIS maps. (Electronic maps of this scale have been made available for Qianliang Hu detention basin and the detail is extraordinary, (even to the description of the users of sports fields).

Where this paper differs from the work of Cheng et al (2002 see below) is that it considers the scale of gridded flood models and suggests that the socio-economic data collection units should be of the same scale rather than a varying scale finite element type modelling as used by Cheng. Wang and Xiang state that “the scale of regular grids should be taken as 500 m x 500 m in urban areas and some complicated landforming regions”. This statement indicates a difficulty faced by all modellers, working at a scale accurate enough to be represent reality in a diverse environment. The area quoted is larger than many farm units and the authors comment on the limitations of the National standard, “regulation for economic benefit analysis calculation of existing flood control projects” (SL206-98). This standard provides for 10 sectors introduced as top level classes and the authors state “it is obvious this taxonomy is only suitable for rural areas”.

Verberg and Chen (2002) considered the impacts of scale when they were examining land use patterns in China. The important part of their study as it relates to this literature review is that they confirm that relationships obtained at a certain scale of analysis may not be directly
applied at other scales or in other areas. This finding is important in that translation of macro or medium scale models to other areas must be done with care and that verification processes need to be followed to insure relevance.

Another study by Xu et al (2002) aimed to design a decision support system (DSS) to help decision makers use uncertainty analysis to satisfy multiple objectives and used a flood damage model to illustrate these two aspects. The paper initially stresses the importance of determining the optimal spatial and temporal resolutions to describe the real system without being too fine or too coarse. They referred to Brasington and Richards (1998) who found that model predictions are grid-size dependent; and major variations results when comparing grid sizes between 100 and 200 metres in the digital elevation model. Xu eventually used a 150 metre grid, much less than the 500 metres specified by Cheng et al. Carroll and Betts (2001) in preparing flood damage estimates for the Nerang River system in Gold Coast City found they had to use a 5 metre grid for the terrain component of the flood damage model as the former 20 m grid was too coarse and produced spurious results. These anomalies were the result of interpolations of bathymetry and land form within the closely spaced canal estates of Gold Coast.

**Medium scale**

The medium scale model approach is widely applied in China when trying to assess damage whilst wide areas are flooded. This requires preliminary analysis to develop stage-damage curves, standard flood surface profiles generated by 1D and 2D models, and mapping the extent of the standard floods. During a flood, on-ground measurements or remote sensing techniques are used to define the real extent of the flood and medium scale damage estimates made. Wang and Xiang (in contrast to Cheng et al) state “the precondition of them is that the potential flood is continuance of historical flood cases, which usually can’t be met because of environmental changes such as new flood control constructions.” Towns are regarded as the smallest statistical unit and damage for agricultural areas is estimated from year book information. The authors adopt a loss rate for crops of 80% when the water depth is less than one metre and 100% when above one metre.

**Macro scale**

Wang and Xiang also believe that macro scale models are deficient in China. Macro basin models as defined in the paper are for whole of river basins and the authors point out the difficulties associated with the uneven spread of economic units and the variation in river networks. They suggest a macro loss rate could be the ratio of the expected damage to GDP which for China in the 1990s was an average of 2.24%. Interestingly flood and storm damage in Vietnam during a similar period accounted for 3% of GDP, (Hanh).

Macro loss rates can be developed by determining the flooded area then using typical criteria from fine scale models, calculate flood damage per capita or per hectare. They consider this a reasonable approach to establish flood risk zones to reflect regional differences and identify where more detailed studies are needed. To overcome the incongruity of extrapolating fine scale results to macro (basin level) estimates, Wang and Xiang caution other practitioners to match the scales of natural features, socio-economic factors and susceptibility to ensure the integrity of the results.
TANGIBLE LOSSES

Direct costs
Direct costs are those caused directly by a flood, not as a consequence of the flood and include actual losses from floodwater. Direct costs that might arise during a flood are less than the potential damages and depend on the warning time available to take mitigating actions. (Potential damage is the total amount of damage that might occur if mitigating actions are not taken). A definition is provided in BTRE 2002 (p. 151):

“Actual damages are the damages that occur due to a flood after preventative measures, such as moving valuables to higher ground, have been taken. They may be measured after a flood, or may be the predicted damages that are likely to be caused by a flood.

Potential damages are the maximum damages that could occur in a flood. In assessing potential damages, it is assumed that no actions are taken to reduce damage.”

Direct costs are fairly easy to calculate given accurate data at a detailed level. Studies are usually done before or after an event and rarely during a flood. This latter aspect was the interest of Cheng et al (2002) in their establishment of a real-time loss assessment model for the Haihe River in Hebei Province China. The paper provides an interesting background to flood loss assessment in China which the authors claim only commenced in the last 20 years or so in an organised manner and state “however up to now there has been no consistent method of assessment in common use”. Recent experience for this YRFCMP project is that while data collection has standardised to some degree, there are many aspects that are not collected or grouped inconsistently. However standardised forms were developed in Hunan Province by the Hunan Hydrology and Water Resources Bureau and data collected is forwarded to the Ministry of Water Resources (pers. comm. Mr Shen Shousan, Hunan Province).

Micro Scale modelling
An aspect of flood damage assessment not readily available to those of Western origin is the ability to obtain detailed information on personal possessions. Cheng, Lu, Su and Zhang (2002) were able to obtain details on “Family property of urban and rural residents includes buildings, factories, transport, vehicles, household appliances, cloths and textiles, articles of everyday use, foodstuffs, livestock and poultry. The loss degree of family property from flood damage is not only related to flood depth, flood duration and flow speed, but also from the character and flood enduring degree of these factors themselves.” This is reasonably difficult at the best of times and personal experience in trying to obtain that information depends greatly on the perception of the integrity of the investigators and the goodwill of the property owner.

Other aspects examined in the above project were the age, durability and height of buildings and the shift in house style and materials over time. This impacted on the loss rates of rural buildings which previously were sun-dried mud brick. However they did notice an uneven distribution between inner and outer suburbs of urban areas with those in the inner area being stronger and more durable. They concluded that outer suburb losses would be higher in a...
severe flood event. The authors also noted adjustments in crop patterns as people moved back into flood plains that had not seen floods for a number of years. Despite these trends the authors concluded that overall loss rates would decline and determined that the year 2000 loss rate would be 80% of the 1986 loss rate.

The study by Cheng et al., appeared to be rigorous in its evaluation of statistic data except for the assumption that a flood would not affect the economy after the flood as discussed earlier (refer Note 2). The study also assumed that the magnitude of the two floods considered would not alter during the intervening periods because of land use change that might otherwise affect run-off rates. Land use changes were discussed in the paper but only in the context of possible damage and not to the hydrological impacts of such changes. Also not stated were the methods to determine the respective flood frequencies. River ratings can change substantially and the duration of flooding is never identical. Different flood frequencies can be attributed to the same flood depending on whether the attribute is rainfall depth, stage (height), flow rate or flood volume. The flood loss / regression coefficients generated by Cheng et al are surprisingly close to unity and might indicate that the concerns expressed above were not factors of sufficient sensitivity to cause disruptions in the analysis.

Micro Scale model loss rates

In a case study of the Haizhu District of Guangzhou City Wang and Xiang develop a fine scale flood loss model for various water depths (half metre intervals up to three metres, and then for over three metres) for various activities for five types of urban assets. Table 1 (below) of the paper provides a list of flood loss rates for urban assets by type of asset by depth. Unfortunately they do not give the units in the table but it is likely they are percentages of the total value of the building and contents. They are also of sufficient value to indicate the ratio of damage by depth and can be applied to gross basins damages.

<table>
<thead>
<tr>
<th>Assets type</th>
<th>Water-Depth (m)</th>
<th>&lt;0.5</th>
<th>0.5-1.0</th>
<th>1.0-1.5</th>
<th>1.5-2.0</th>
<th>2.0-2.5</th>
<th>2.5-3.0</th>
<th>&gt;3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>House</td>
<td></td>
<td>8.0</td>
<td>12.0</td>
<td>17.0</td>
<td>21.0</td>
<td>26.0</td>
<td>31.0</td>
<td>35.0</td>
</tr>
<tr>
<td>First stair of building</td>
<td></td>
<td>3.0</td>
<td>6.0</td>
<td>9.0</td>
<td>12.0</td>
<td>16.0</td>
<td>19.0</td>
<td>22.0</td>
</tr>
<tr>
<td>Family property</td>
<td></td>
<td>9.0</td>
<td>19.0</td>
<td>26.0</td>
<td>33.0</td>
<td>38.0</td>
<td>46.0</td>
<td>58.0</td>
</tr>
<tr>
<td>Fixed asset</td>
<td></td>
<td>10.0</td>
<td>15.0</td>
<td>18.0</td>
<td>22.0</td>
<td>26.0</td>
<td>29.0</td>
<td>32.0</td>
</tr>
<tr>
<td>Circulating funds</td>
<td></td>
<td>14.0</td>
<td>20.0</td>
<td>23.0</td>
<td>28.0</td>
<td>31.0</td>
<td>34.0</td>
<td>37.0</td>
</tr>
<tr>
<td>Fixed asset</td>
<td></td>
<td>12.0</td>
<td>16.0</td>
<td>20.0</td>
<td>25.0</td>
<td>29.0</td>
<td>34.0</td>
<td>38.0</td>
</tr>
<tr>
<td>Circulating funds</td>
<td></td>
<td>16.0</td>
<td>21.0</td>
<td>25.0</td>
<td>30.0</td>
<td>34.0</td>
<td>39.0</td>
<td>43.0</td>
</tr>
<tr>
<td>Engineer facilities</td>
<td></td>
<td>8.0</td>
<td>12.0</td>
<td>17.0</td>
<td>22.0</td>
<td>27.0</td>
<td>32.0</td>
<td>35.0</td>
</tr>
</tbody>
</table>

In an earlier project, Chen (1999) 2 examined, among other matters, various loss rates from flooding in China and developed an assessment system (FLOODES) that could be applied to various kinds of floods. He makes a comparison in his Table 6.1 of the loss rate in Zhumadian in Henan Province and Jingjiang detention basin and notes that although the economic condition and the inundation characteristics between the two places are different,

“The loss rate trend of the main inundation objects of Jingjiang area match real data obtained through investigation in Zhumadian area of Henan Province. This shows that we can take the information from other areas as reference when we determine loss rate of the study area.”

2 This work is only partially translated and full commentary is not possible.
Table 6.1 from Chen (1999)

<table>
<thead>
<tr>
<th>Item</th>
<th>Zhumadian area</th>
<th>Jingjiang basin</th>
<th>Item</th>
<th>Zhumadian area</th>
<th>Jingjiang basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crops</td>
<td>72.5</td>
<td>100</td>
<td>Agricultural m/c</td>
<td>34.1</td>
<td>60</td>
</tr>
<tr>
<td>Forestry</td>
<td>42.6</td>
<td>31.9</td>
<td>Industrial</td>
<td>17.7</td>
<td>53.6</td>
</tr>
<tr>
<td>Aquatic products</td>
<td>51.8</td>
<td>76.2</td>
<td>Commercial</td>
<td>67.8</td>
<td></td>
</tr>
<tr>
<td>Water conservation</td>
<td>42.7</td>
<td>50</td>
<td>Cereal</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Power system</td>
<td></td>
<td>100</td>
<td>Cultural and health</td>
<td></td>
<td>83.8</td>
</tr>
<tr>
<td>Telecommunications</td>
<td></td>
<td>60</td>
<td>Urban residential</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>Communications</td>
<td></td>
<td>50</td>
<td>Rural residential</td>
<td></td>
<td>70</td>
</tr>
</tbody>
</table>

This table shows some variation in the loss rates between the two areas but they are of similar magnitude. The variations that occur are likely due to the depth and the duration of flooding that would be experienced in Jingjiang basin.

Chen includes Table 6.3 below as an example of research done in 1990 (based in 1980 prices) on building and contents values in the United States where it was found that the ratio of the value of the contents to the value of the structure was 30%. Chen does not say in the accompanying paragraph whether this ratio can be applied to Chinese housing conditions.³ Later in Tables 6.6 and 6.7 he states the average value of internal assets is 22700 RMB and the relocation cost of a house as 51300 RMB at 1990 prices. The ratio is somewhat higher than the United State figures in Table 6.3.

Table 6.3, Chen (1999) Residential Contents values

<table>
<thead>
<tr>
<th>Total area (sq ft)</th>
<th>Value of furniture (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Below 1000</td>
<td>7800</td>
</tr>
<tr>
<td>1000 – 1500</td>
<td>8500</td>
</tr>
<tr>
<td>1500 – 2000</td>
<td>10700</td>
</tr>
<tr>
<td>Above 2000</td>
<td>12600</td>
</tr>
</tbody>
</table>

Information is also provided on the damage loss rate for crops that not only provides a relationships for damage with respect to depth, but also the duration of flooding and the depth of sand/silt deposited during the flood.

Table 6.4 (Chen 1999) Damage Rate of Crops

<table>
<thead>
<tr>
<th>Flooded depth (m)</th>
<th>Flooded depth (days)</th>
<th>Depth of sand/silt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 0.5</td>
<td>0.5 – 0.99</td>
</tr>
<tr>
<td>Paddy</td>
<td>0.21</td>
<td>0.24</td>
</tr>
<tr>
<td>Paddy on dry land</td>
<td>0.2</td>
<td>0.31</td>
</tr>
<tr>
<td>Sugar cane</td>
<td>0.11</td>
<td>0.37</td>
</tr>
<tr>
<td>Cabbage</td>
<td>0.42</td>
<td>0.58</td>
</tr>
<tr>
<td>Vegetable</td>
<td>0.19</td>
<td>0.20</td>
</tr>
</tbody>
</table>

³ I recall this ratio being applied by a Chinese author in a paper but can not find the reference.
Table 7.2 Depth – Damage Relationship Estimation for Structures

<table>
<thead>
<tr>
<th>Inundation depth</th>
<th>Loss rate %</th>
<th>Structural loss RMB</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.4</td>
<td>11</td>
<td>5000</td>
</tr>
</tbody>
</table>

The ANFAS project is a research project of the European Research Consortium of Informatics and Mathematics, [www.ercim.org/ANFAS](http://www.ercim.org/ANFAS). Its aim is to develop a decision support system for flood prevention and protection with particular emphasis on flood damage and how flood damage indicators might be used for land use planning, (pers. comm.. Prof V. Prinet, Chinese Academy of Science, Chinese team leader, ANFAS project in China).

One are being used as a case study is the Jingjiang detention basin, upstream of and to the north west of Qianliang Hu detention basin. In this case study, land use indicators were developed from remote sensing techniques.

The impact assessment model divides economic loss into both direct and indirect costs as in Australia. Loss rates have been adopted using water depth as the controlling criteria for agriculture, forestry, pastoral, fisheries, industrial and commercial, residential and establishment costs (electricity, roads, etc.). These are simple relationships but it is not known from where the information was sourced. The following tabulations are available on the ANFAS web site [http://digitalearth.net.cn/anfas](http://digitalearth.net.cn/anfas).

"3.1 Agricultural Loss Model

The synthetically loss model for agriculture is as tab.1.

Tab.1 Agricultural synthetically Loss Model

<table>
<thead>
<tr>
<th>Water Depth (m)</th>
<th>0-0.5</th>
<th>0.5-1</th>
<th>1-1.5</th>
<th>&gt;1.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss Rate (%)</td>
<td>60</td>
<td>80</td>
<td>95</td>
<td>100</td>
</tr>
</tbody>
</table>

If the flood duration is taken into consideration, the model for rice is as tab.2.

Tab.2 Rice Loss Model Considering Flood Duration

<table>
<thead>
<tr>
<th>Variety of rice</th>
<th>Growth period</th>
<th>Mathematical model</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Chinese Rice 691&quot;</td>
<td>Tillering stage</td>
<td>Y=0.32431H^{1.08}+0.477</td>
</tr>
<tr>
<td></td>
<td>Boot stage</td>
<td>Y=0.048477H^{1.248}+0.705</td>
</tr>
<tr>
<td></td>
<td>Heading stage</td>
<td>Y=0.017289H^{1.675}+0.455</td>
</tr>
<tr>
<td>&quot;Chinese Rice 910&quot;</td>
<td>Mid Tillering stage</td>
<td>Y=0.57743H^{1.104}+0.43</td>
</tr>
<tr>
<td></td>
<td>End Tillering stage</td>
<td>Y=0.44488H^{1.858}+0.488</td>
</tr>
</tbody>
</table>
Where:

- $Y$ – reduction rate of output of rice (%)
- $H$ – water depth (cm)
- $T$ – duration (days).

3.2 Forestry Loss Model

**Tab. 3 Forestry synthetically Loss Model**

<table>
<thead>
<tr>
<th>Water Depth (m)</th>
<th>0-1</th>
<th>1-2</th>
<th>2-3</th>
<th>&gt;3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss Rate (%)</td>
<td>15</td>
<td>30</td>
<td>40</td>
<td>50</td>
</tr>
</tbody>
</table>

3.3 Pastoral and Fishery Loss Model

**Tab. 4 Pastoral synthetically Loss Model**

<table>
<thead>
<tr>
<th>Water Depth (m)</th>
<th>0-1</th>
<th>1-2</th>
<th>2-3</th>
<th>&gt;3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss Rate (%)</td>
<td>15</td>
<td>20</td>
<td>40</td>
<td>60</td>
</tr>
</tbody>
</table>

**Tab. 5 Fishery synthetically Loss Model**

<table>
<thead>
<tr>
<th>Water Depth (m)</th>
<th>0-1</th>
<th>1-2</th>
<th>2-3</th>
<th>&gt;3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss Rate (%)</td>
<td>80</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

3.4 Industrial and Commercial Loss Model

**Tab. 6 Industrial and Commercial synthetically Loss Model**

<table>
<thead>
<tr>
<th>Water Depth (m)</th>
<th>0-1</th>
<th>1-2</th>
<th>2-3</th>
<th>&gt;3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss Rate (%)</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>

3.5 Residential Property Loss Model

**Tab. 7 Residential Property synthetically Loss Model**

<table>
<thead>
<tr>
<th>Water Depth (m)</th>
<th>0-1</th>
<th>1-2</th>
<th>2-3</th>
<th>3-4</th>
<th>&gt;4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family Impact Ratio</td>
<td>1/3</td>
<td>1/3</td>
<td>2/3</td>
<td>2/3</td>
<td>4/5</td>
</tr>
<tr>
<td>Loss Rate (%)</td>
<td>30</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
</tr>
</tbody>
</table>

3.6 Establishment Loss Model

**Tab. 8 Establishment synthetically Loss Model (Loss Rate %)**

<table>
<thead>
<tr>
<th>Water Depth (m)</th>
<th>0-1</th>
<th>1-1.5</th>
<th>1.5-2</th>
<th>2-2.5</th>
<th>2.5-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro Establishment</td>
<td>18</td>
<td>22</td>
<td>26</td>
<td>30</td>
<td>34</td>
</tr>
<tr>
<td>Electric Power Supply</td>
<td>11</td>
<td>26</td>
<td>28</td>
<td>31</td>
<td>34</td>
</tr>
<tr>
<td>Road</td>
<td>20</td>
<td>30</td>
<td>30</td>
<td>40</td>
<td>40”</td>
</tr>
</tbody>
</table>

Table 2 above cannot be used unconditionally as there limits to duration and depth that can be applied to the formulae. Beyond these limits use of the models is nonsensical. If for example a depth of one metre and duration of 30 days are applied to the rice “heading” relationship, the loss rate exceeds 100%.

The book by Wang Qing (1999) is printed in Chinese and only those portions dealing with flood loss rates have been translated. From the contents page, this publication appears to be one of the more complete works on flood damage as its examination includes:

- Flood damage analysis systems and approaches
- Estimation indices
- Socio-economic factors
- Flood risk analysis methods, and
- Disaster reduction decision making theory.

Its Table 5.2 lists the following loss rates:
Activity | Loss rate %
--- | ---
Agriculture | 90 – 100
Forestry | 20 – 60
Aquaculture | 70 – 100
Husbandry | 15 – 60
Private property | 50 – 60
Agricultural machinery | 50 – 60
Business | 60 – 80
Water conservancy | 20 – 60
Communications | 30 – 60
Power | 50 – 100
Telecommunications | 60 - 90

Tables 5-10, 5-11, 5-12, 5-13 and 5-14 provide loss rates for rice, wheat, corn, soy and vegetables for other river basins in China and typical values are:

### Loss rates for plantings (%)

<table>
<thead>
<tr>
<th>Flood depth</th>
<th>&lt; 0.5 m</th>
<th>0.5 – 1.0 m</th>
<th>1.0 - 2.0 m</th>
<th>2.0 – 3.0 m</th>
<th>&gt; 3.0 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>60 - 90</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Wheat</td>
<td>25</td>
<td>75</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Corn</td>
<td>50</td>
<td>95</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Soy</td>
<td>50</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Vegetables</td>
<td>55</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Millet</td>
<td>25</td>
<td>88</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Flood duration plays a part, but once duration exceeds two weeks, the loss rate approaches 100% for even shallow depths of flooding.

Property losses occurred in the city of Wuhan in 1983 and the loss rates of that time are still considered realistic for today, (pers. comm. Dr Zhan Xiao Guo, Yangtze Scientific Research Institute, Wuhan (author Dec 2001)). Typical loss rates for commerce, services, transportation, organisation were all reported as being between 10% and 30%. Residential property losses varied between 30% and 100% (Table 5.21). Indirect losses were also reported in Table 5.22 as 23.1% of the total economic loss (i.e., direct losses were 76.9%), a ratio of almost 1:3. This figure is reasonably consistent with the findings of BTR Report 103 (p. 73, 2001).

Table 5.24 provides information on the property loss rate of individual residents of Wuhan City.

<table>
<thead>
<tr>
<th>Depth of inundation (m)</th>
<th>&lt; 1</th>
<th>1 - 2</th>
<th>2 - 3</th>
<th>3 - 4</th>
<th>&gt; 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of inundated families affected</td>
<td>1/3</td>
<td>1/3</td>
<td>2/3</td>
<td>2/3</td>
<td>4/5</td>
</tr>
<tr>
<td>Family loss rate</td>
<td>30</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
</tr>
</tbody>
</table>

This table is identical to the Table 7 of the ANFAS work and is probably the source of ANFAS loss rates.

Tables 5.25 and 5.26 provide estimates of the number of days of inundation and make comparisons of inundation duration and recovery period.

<table>
<thead>
<tr>
<th>Inundation (days)</th>
<th>&lt; 30</th>
<th>30 - 90</th>
<th>&gt;90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restoration period (days)</td>
<td>20</td>
<td>30</td>
<td>35</td>
</tr>
</tbody>
</table>

Later in this chapter, considerable detail is provided on the types and number of agricultural machines owned by rural entities, and the type and number of consumables for every 100
rural families for individual years for the period 1985 to 1997. This level of detail provides some level of surety that sufficient research has been undertaken to qualify the accuracy of the loss rates.

Comparisons of the various loss rates described above are made below but need to be verified with data available for Qianliang Hu detention basin before loss rates are finally selected for application to Qianliang Hu and other detention basins within the middle and lower reaches of the Yangtze River. It should be remembered that flooding by breach or overtopping of a dyke can be of long duration and quite deep and in most cases loss rate will approach maximum values. It is only when flooding is local or controlled that lesser depths need to be considered. In most cases flooding of the Yangtze will be exceed one month in duration.

**Loss rates (%)**

<table>
<thead>
<tr>
<th>Authority</th>
<th>Chen (1999)</th>
<th>ANFAS</th>
<th>Wang Qing (1999)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zhumadian area</td>
<td>Jingjiang detention basin</td>
<td>General crops</td>
</tr>
<tr>
<td>Crops</td>
<td>72.5</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Cereal</td>
<td>70</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Paddy &lt; 1m depth</td>
<td></td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>Paddy – dry land</td>
<td></td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>Sugar</td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Cabbage</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Vegetable</td>
<td></td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>Edible plant</td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Other farmland</td>
<td></td>
<td></td>
<td>91</td>
</tr>
<tr>
<td>Forestry</td>
<td>42.6</td>
<td>31.9</td>
<td>50</td>
</tr>
<tr>
<td>Pastoral</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Husbandry</td>
<td></td>
<td></td>
<td>15 – 60</td>
</tr>
<tr>
<td>Aquatic products</td>
<td>51.8</td>
<td>76.2</td>
<td>60</td>
</tr>
<tr>
<td>Water conservation</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roads</td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Power system</td>
<td></td>
<td>100</td>
<td>34</td>
</tr>
<tr>
<td>Agricultural machinery</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td></td>
<td>53.36</td>
<td>30</td>
</tr>
<tr>
<td>Commercial</td>
<td></td>
<td>67.8</td>
<td>30</td>
</tr>
<tr>
<td>Cultural and health</td>
<td>83.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telecommunications</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communications</td>
<td></td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Urban residential</td>
<td></td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Residential property</td>
<td></td>
<td>70</td>
<td>100</td>
</tr>
</tbody>
</table>

The actual loss rate for primary production for Qianliang Hu detention basin in 1996 is estimated at between 80% and 85% (refer calculations on page 19).
Medium Scale modelling

In a case study for the Dujiatai flood diversion and storage basin in the Hanjiang River near Wuhan, Mei (2002) links both flood damage risk assessment with policy analysis for development and mitigation. He states that in undertaking the risk assessment three matters should be analysed: hazard phenomenon, vulnerability and hazard influence which describe the adverse impacts of a flood on natural ecological and socio-economic systems.

Of interest to this literature review however is confirmation that losses in this part of the Yangtze system generally conform to other areas of the Yangtze River system. Mei suggests that the application of a flood damage estimation procedure developed for one or two basins as fine scale models can be appropriately applied to other part of the river system.

Mei contrasts the implications of timing of losses of life and property to the losses to agriculture. The former are independent of the time flooding occurs, but not so with agriculture. As damage is dependent on the age of the crop when the flood occurs Mei proposes an approach that calculates the joint probability of a particular stage of growth and flood event in discrete intervals in the growing season. He suggests that this approach be used in land use planning to determine the net yield of the land. He defines net yield as the value of the crop at maturity less the composite crop-loss rate. This particular methodology is technically correct for application to land use choices but has little relevance to flood damage estimation as would be applied in the current context for the detention basins of the Yangtze River. Timing is important to the value of crops but in the context of this study may not be relevant (refer page 31 for comment).

Macro scale modelling

Cheng et al set as their fundamental objective, that results from a real-time model should be acceptable and should reflect the final total using accurate data and an adopted assessment process. They used data from a flood of the Haihe River in Hebei Province but updated their economic information to the year 2000. (This accounting for inflation has also been recommended by the American Institute of Economic Research 1999 – reported by Mitchell and Thomas on page 79). Cheng’s method produced a relationship for flood loss against gross domestic product (GDP) for floods of two magnitudes in the form of equation:

\[
\text{Flood loss} = A \times (\text{GDP})^B,
\]

where A and B are constants for each flood magnitude, in this case for the 2% and 5% annual exceedence probable (AEP) events of 1963 and 1996 respectively, and the regression coefficient

- \( R^2 = 0.9822 \) for the 2% AEP event and
- \( R^2 = 0.9953 \) for the 5% AEP event.

\[
\begin{array}{cccc}
\text{and} & 5\% \text{ AEP} & 2\% \text{ AEP} \\
A & 0.733 & 4.189 \\
B & 0.7724 & 0.7331
\end{array}
\]

GDP for Qianliang Hu detention basin can be estimated from Provincial and County labour productivity and the population. Overall labour productivity for primary industry in Hunan Province in 1995 was 3304 RMB per capita, (Hunan 2002). The similar statistic for Huarong
County is derived from GDP/county population (1,816,940,000 RMB / 716,200 people) which equates to 2537 RMB per capita.

GDP for Qianliang Hu is approximately 171,241,900 RMB which if then applied to Cheng et al’s formula above provides a flood loss of 1,677,800 RMB (assuming the damage impact of the 1996 flood was from a 5%AEP event). Actual primary industry losses in the basin were 143,700,000 RMB (an overall loss rate of 84%). This comparison indicates that river basin (macro data cannot be applied at detention basin level.

The interesting part about the methodology is the way economic factors were related to the two flood events and the use of statistic year book information to develop their “historical model method”. They applied each flood to what are called “repeat years”, years for which economic statistics were available, typically at five yearly intervals. Factors used to standardise the statistics were “coefficient of loss” (loss rate); price indices; and conversion factors for property value were applied retrospectively to each “repeat year”. Loss rates were developed for agriculture and then grouped for forestry, animal husbandry and fisheries. These loss rates varied over time for the same magnitude flood due to changing economic circumstances but gave good indications of losses that might be able to be applied to other river basins. Typical loss rates for agriculture for example varied from about 75% to 95% in a 2% AEP event, a similar loss rate to those stated by Wang and Xiang.

The authors also considered the age, degradation, working life and renewal rate of flood control infrastructure and changing standards required for building construction and public safety to determine the effective loss rate and consequent damage for the theoretical flood “repeat year”. For urban situations many houses were two or more stories in height and would have been unaffected at the upper levels by flood water. This meant their condition would have unlikely to have changed much in the period 1986 to 1996. For those building more susceptible to flood damage Cheng et al suggest a drastic change in character would have occurred with new buildings being more substantial and better able to withstand flooding than their predecessors. They also state that there has been an uneven distribution of building in the outer suburbs thereby affecting flood damage estimates. Counteracting the urban improvement is the fact that a number of floodplains are being repopulated due to the time period since the last major flood. But overall private property losses are suggested would have fallen. Cheng et al state that the loss rate would be about 0.8. This is significantly higher than loss rates suggested by others.

Zhan and Tan examine the use of remote sensing techniques to determine the extent of flooding at a macro scale level and how those techniques might be used to determine flood loss. They developed an “Index of flood damage degree (FDD)” which they use to evaluate the relative degree of disaster loss between various parts of the Yangtze River basin. In the paper four “evaluation principles” were specified: evaluation period – recent years; evaluation scope – where flood disasters occur most frequently; emphasising direct losses and making attempts at indirect loss considerations; and evaluating absolute and relative losses.

Zhan and Tan state that losses can be assessed by insurance compensation data, models of disaster factors and losses and empirical coefficients for some industries. They report the items that should be included together with indications of how indirect losses can be broadly estimated (refer section on indirect losses below).
Another aspect of macro and medium scale modelling is that of population where unit per capita costs derived for one area have been applied to other areas. This must be done with caution and population stability should be checked from provincial and county yearbooks.

Wang Qing (1999) made comparisons between actual and estimated populations. His Table 5.33 showed the estimates can vary by ±10% with typical outliers being in the range ±16% for a number of cities in China. This work was published in 1999 and would be based on an earlier national census. This time elapse would contribute to the drift in estimate and it should also be remembered that there has been a dramatic shift in population from rural areas to cities, (Hunan 2002, Hubei 2002, Cheng, X.T. 2002).

Another aspect of damage modelling that was examined in Wang Qing’s book was the relationship between population density and farm land for various counties using 1994 statistics. This information is sometimes used in macro scale modelling where relationships between land use and population were sometimes used to calculate economic losses. Table 6.4 of this book lists population and areal statistics for some 88 counties. The statistics indicate that no useful relationships can be developed for population and land use.

**Indirect costs**

These are losses incurred as a consequence of an event but are not due to the direct impact. Costs included in this grouping are clean up, disruption to business, emergency response and emergency accommodation for evacuees. (Table 4.6 below is reproduced from page 74 of BTE 2001 p73).

<table>
<thead>
<tr>
<th>Loss category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disruption of business</td>
<td>• Manufacturing production</td>
</tr>
<tr>
<td></td>
<td>• Retail, distribution, office</td>
</tr>
<tr>
<td></td>
<td>• Leisure services</td>
</tr>
<tr>
<td>Disruption of networks</td>
<td>• Communications</td>
</tr>
<tr>
<td></td>
<td>• Road traffic</td>
</tr>
<tr>
<td></td>
<td>• Other traffic</td>
</tr>
<tr>
<td></td>
<td>• Public utilities</td>
</tr>
<tr>
<td></td>
<td>• Water supply</td>
</tr>
<tr>
<td></td>
<td>• Sewage and sewage treatment</td>
</tr>
<tr>
<td></td>
<td>• Gas</td>
</tr>
<tr>
<td></td>
<td>• Electricity</td>
</tr>
<tr>
<td></td>
<td>• Telecommunications</td>
</tr>
<tr>
<td></td>
<td>• Computer control systems</td>
</tr>
<tr>
<td>Disruption of public services</td>
<td>• Additional heating/drying out costs</td>
</tr>
<tr>
<td>Disruption of households</td>
<td>• Other miscellaneous costs</td>
</tr>
<tr>
<td>Emergency service costs</td>
<td>• Local government</td>
</tr>
<tr>
<td></td>
<td>• Police</td>
</tr>
<tr>
<td></td>
<td>• Fire brigades</td>
</tr>
<tr>
<td></td>
<td>• Ambulance services</td>
</tr>
<tr>
<td></td>
<td>• Flood defence agencies</td>
</tr>
<tr>
<td></td>
<td>• Military aid</td>
</tr>
<tr>
<td></td>
<td>• Voluntary services</td>
</tr>
</tbody>
</table>


There is some overseas evidence that indirect costs are proportional to direct costs and the size of the disaster, (National Research Council, 1999, p. 35). It was concluded by BTE (2001 p73) that for recent Australian floods indirect tangible losses were 25% to 40% of the direct losses. BTRE confirm these rates and state that estimates of indirect costs can be set as a proportion of the direct losses.
Clean up costs can be estimated from the number of person days per household, refuse transport and disposal, and has been found in Australia to be generally proportional to depth, (BTRE 2002, p.82). BTE (2001, p. 83) reported that residential clean up time was also dependent on prior clean up experience (based on SMEC’s 1974 study of the Brisbane flood).

Business disruption costs are taken as the loss opportunity of adding value, *i.e.* days of lost trading. There are also ongoing financial costs related to additional interest costs incurred when funds have to be borrowed for disaster recovery associated with the re-establishment of the productive facility and the maintenance of working capital until full recovery.

Emergency response costs can be estimated from the number of personnel, duration of involvement, their accommodation and transport costs. They are often assumed to be proportional to the depth of flooding. (The total cost per dwelling is assumed in Australia to be the labour cost plus 50% - BTE 2001). Emergency accommodation costs are based on per household rate plus a per capita rate. In Australia much of this work is performed by volunteers in their own time thereby complicating the damage calculation. This in fact is an intangible cost and could be treated as such.

UNESCAP state that utility indirect losses would include the effects of interruption of services, loss of revenue and other income and costs of providing emergency supply. Indirect residential losses include the costs of evacuation, provision of emergency accommodation and damage relief costs. UNESCAP also suggest that indirect losses for commerce and industry should include lost wages, salaries and revenues, loss of contracts and other business and additional operating costs.

This is in direct contrast to BTE (2001 page xv) which states that indirect cost calculations should exclude the costs of disruption to business or industry. They suggest that at a national perspective, business disruption to one geographic sector of an economy is taken up by another geographic sector and involves a transfer between producers without a significant loss in national economic efficiency. However they do state there may be occasions when the transfers between producers involves additional transportation costs and these are legitimate inclusions in the indirect cost category.

Zhan and Tan also refer to indirect losses and include in that category flood control cost, consequent losses in other areas, decreased incomes and the additional costs during the rebuilding period. The consequent losses in other areas and additional rebuilding costs do not seem to have been mentioned in other literature covered for this review and are usually excluded from normal Australian methodologies. They are also excluded from calculation methods that use small or medium scale flood damage modelling. In the writer’s view they are valid categories and should be included. This means that comparisons of the GDP for the years of and either side of a flood disaster used for flood damage modelling must be made a part of the calibration process.

Zhan and Wang state that that there are no computational methods currently used in China for attributing economic losses to fatalities but injury costs are based on statistical data. They report three injuries to each fatality.

Indirect losses have been assessed by Zhan and Wang as follows:
Yangtze River Flood Control and Management Project  
Literature Review for a Socio-Economic Impacts Assessment Procedure for Qianliang Hu detention basin

- Farming 28% of direct losses based on work done for the Three Gorges Project;
- Infrastructure 30% to 50% of direct losses including roads, rail, bridges, stations and docks; and
- Industrial and commercial 30% of direct losses.

They do not provide any indication of indirect losses for private property losses but do outline two methodologies to estimate population distribution. The first is a simple ratio of flooded area and uniformly distributing population and contrasts with the population statistics contained in Wang Qing’s book (refer page 24). The second simulates residential distribution by “exterior auxiliary variables” such as land elevation, distance from traffic lines, density of residential points and distance from main cities. They state both methods provide reasonable estimates but do not provide details of the parameters used in the estimation process or of the base data that provides validates the statement.

It is possible to have three crops per year in the middle reach of the Yangtze River system, each with an average three month growing season. The usual estimate of the disruption to agriculture caused by a flood is five months. This impact implies that not only is one crop lost (direct loss) but the next also during which time evacuees have to be fed and housed. It is this second crop that represents an unrealised opportunity of perhaps 50% to 80% loss of production depending on the duration of the flood.
INTANGIBLE LOSSES AND IMPACTS

Intangible losses are those that cannot be valued in monetary terms (that is, they have no market value, (BTRE 2002, p. 154). They include the loss of memorabilia; death, injury or illness caused by flooding, environmental impacts and social costs. Social costs are extraordinarily difficult to quantify as many of the impacts are psychological and impact on people in different ways (fear, stress, and ongoing medical problems such as injuries caused by lifting, causing ongoing burdens for the community).

Parker (1999, p. 39) classified intangible flood impacts as primary, secondary and tertiary. Primary impacts include those resulting from loss of life, physical injury and loss of heritage sites. Secondary losses result from increased stress and ill health. Tertiary effects include homelessness, loss of livelihood and loss of sense of community. Each of these impact on the well-being of a community as a whole and its ability to function in its normal manner.

Social impacts

Whilst the earlier part of this review examines the factors relating to economic loss, very little is has been quantified on the social impacts of flooding which are often said to have an effect equivalent to 50% to 100% of the direct financial costs of a flood. Such costs relate to ongoing medical expenses and disruptions to future productivity resulting from injury or psychosomatic illness, loss of documents, disruption to social structure, fear of heavy rain, and fatalities. Factors to estimate the total impact would probably include the number of people flooded; the number of people who lost a family member or member of a team; the position or status of the person and their circle of influence; the number of homes destroyed or substantially damaged; jobs lost and disruptions to productivity; education; impact on flood flighting personnel and those caring for evacuees, and destruction of wealth. Most of these are difficult to quantify.

In contrast to the standard economic impact methodologies used in Western countries, Rumi (2002) outlined a different classification system to discuss the social effects of the disastrous 1998 flood in Bangladesh. He categorised damage under three broad headings and then allocated tangible and intangible impacts according to his headings as follows. Each item has consequent impacts on the next and successive items.

- **Human population:**
  - Damage to dwellings and property,
  - Social problems with flood and water supply,
  - Malnutrition and loss of resistance power,
  - Morbidity and mortality,
  - Decrease in earning ability.
  - Financial hardship and regain previous position, and
  - Occupation displacement and low income level.

- **Environmental degradation:**
  - Loss of bio-diversity,
  - Soil erosion, and
  - Water pollution.
• Stagnant economic growth:
  o Damage of infrastructure and disruption of communication system,
  o Loss of standing crops and livestock and fisheries,
  o Loss of industrial products,
  o Reduction of export trade, and
  o Break in education system.

Rumi points out the devastation to housing (saturation of mud plinth and walls and impact on rice production (drop of 3.5 million tonnes). Environmental degradation occurred through water pollution (sewage mixing with industrial waste and toxic chemicals) and consequent health impacts. Oxygen deficiency and pH imbalance caused many plants and fish stocks to die. The impacts of malnutrition and mortality were felt, as were the social impacts of harassment of families and young girls who were forced to live on the roadside.

In his Keynote lecture to Flood Defence 2002, Cheng Xiaotao noted that although casualties in flood plains have decreased the numbers of casualties caused by surging streams and mudslides in gullies and valleys have increased. Cheng also reported that urban population in China has increased from 8.3% in 1952 to 26.4% in 1990 to 36.1% in 2000. This has had a profound change in the society with urban population densities increasing by about 80% in the period 1992 to 2000 and a decline in the number of people exposed to riverine flooding. This might partially explain why the fatalities attributed to flooding in 1998 were about one tenth of those of the 1954 flood.

Following the Red River (Manitoba) flood in 1997, a strategic research workshop was held to investigate the social impacts of flooding (Grant 1997). One of the conclusions of this workshop was to highlight some of the areas where more knowledge of impacts was needed. These included:

- effects on future welfare and care of the elderly, (and in China the consequent impacts on younger member(s) of the family);
- Economic impacts on families and businesses;
- How were business affected (closures, bankruptcies, improvements)?
- Were those evacuated better off if family or social groups could be kept together?
- What are the effects of the mode of hospitality (where evacuees stayed)?
- What were the environmental effects of flooding on peoples’ homes?
- How did the flood effect individual communities?

These matters indicate that all the facets of a society should be included in a social impact assessment.

**Mortality estimates**

Fatalities obviously have a direct economic consequence through loss of productive capacity, but also indirectly through the effects on the rest of the family who might not work as efficiently as they would if the fatality had not occurred.

An indication of the quantum of the cost of a fatality can be estimated by multiplying the number of fatalities by GDP per person for the region. Although a simplistic method, it ignores the individual’s worth to productive capacity and future earnings potential. Another difficulty is estimating the likely number of fatalities from an event and separating direct and indirect fatalities.
Loss of life has economic consequences and these have been estimated at approximately AU$1.4 million per fatality at 2001 prices, (BTE 2001, p. 132). They also reported that UK studies indicated that attendances at doctors’ surgeries and hospitals increased after a flood, but the rate of attendance was dependent upon prior flood experience and attendance diminished with that experience. On page 52 of the same report, flood statistics for Australia indicate the occurrence of about one fatality for every 10 serious injuries, and later on page 103 suggest that there is a ratio of one serious to three minor injuries.

Using US data, Mitchell and Thomas (2002) noted that the quantum of flood damage is not an indicator of flood fatalities. They also note that injury statistics are not sufficiently detailed to make a similar comparison.

In his website Barton states

“USGS studies indicate that life and property losses from earthquakes, hurricanes, floods, and tornadoes exhibit fractal scaling behavior which can be used to forecast future losses”. He describes fractal scaling as: “plots of logarithms of the size and cumulative frequency data follow a straight line. The slope of this line is the scaling exponent or fractal dimension … Preliminary results suggest that the loss of life and property due to natural disasters exhibit self-similar scaling behavior. It is this self-similar scaling property that allows use of frequent small events to estimate the rate of occurrence of less frequent, larger events. Examining the fractal behavior of loss data for disasters of all scales has important advantages because one can forecast the probability of occurrence of a disaster over a wide range of years (1 year to 1,000 years); compare one type of disaster with another; compare disasters in one region with similar disasters in another region; and, measure the effectiveness of planning and mitigation strategies.”

Chen’s (1999) Table 2.1 below provides an interesting comparison to Barton that generally supports Barton’s findings on the fractal nature of injury and fatality. Moreover, these are the only injury statistics for China found so far in the Literature search. In contrast to Mitchel and Thomas the table seems as though it might be useful to provide an estimate of injuries and fatalities by simple correlation with flood damage once that has been calculated. However the injury and death statistics are based on historical events probably dating back to a major Yangtze River flood in 1954 and may be based on raw statistics, unmodified by social, mechanical, and educational changes that might have occurred in the last 50 years. It should be expected that improvements in transport infrastructure, communication, education, flood awareness, stronger dykes and flood management sophistication would contribute to a falling mortality rate and perhaps an increase in the corresponding injury/death ratio.

It is not stated in Barton’s web-site whether corresponding improvements in the United States were taken into account in the development of the fractal theory.

Table 2.1 FDDs for Some Typical Flood Damage Cases

<table>
<thead>
<tr>
<th>i</th>
<th>Casualties</th>
<th>Injured</th>
<th>Total economic loss (10^4 RMB)</th>
<th>FDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>10</td>
<td>10</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>100</td>
<td>100</td>
<td>3.47</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>300</td>
<td>520</td>
<td>5.00</td>
</tr>
</tbody>
</table>

FDD means Flood Damage Degree and is an economic indicator used to compare flood events in terms of flood damage.
“Death and casualty damage” are mentioned by Zhan and Tan but state there are no definite computational methods for calculating losses unlike values ascribed to fatalities by BTE (2001). Losses attributed to the wounded are calculated by statistical data. Zhan and Tan also report that personal injury rates are taken as three times the fatality rate in contrast to the Chen’s ratio of 1:10. By comparison Australia’s statistic is 1 fatality: 10 serious injuries: 30 minor injuries rate reported by BTE (2001). Given the differing environmental conditions and social structure in China and Australia, perhaps Zhan’s and Tan’s ratios are closer to reality. This could be the subject of further research as not only is the personal injury rate high in China, but the number of fatalities is commensurately greater.

The National Safety Council (USA) in 1967 published the 'calculated' risk associated with natural hazards based on the data and models that were available at the time and estimated there could be $2.5 \times 10^{-10}$ fatality/person-hour of exposure for flooding.


### Comparison of natural disaster fatalities in the United States.

![Graph comparing natural disaster fatalities in the United States.](http://marine.usgs.gov/fact-sheet/nat_disasters/U.S._disaster_fatal.gif)

The commented:

*Cumulative size-frequency distributions for annual earthquake, flood, hurricane, and tornado fatalities. In addition to demonstrating linear behavior over 2 to 3 orders of magnitude in loss, these data group into two families. Earthquakes and tornadoes are associated with relatively flat slopes ($D=0.4 - 0.6$); while floods and tornadoes have steeper slopes ($D=1.3 - 1.4$). Open symbols were not used to calculate slope of lines.*

In a recent paper, Jonkman *et al* stated that in the year 2000 the death toll from flooding worldwide was about 6000. Their paper provides an overview of loss of life models for sea and river floods and concluded that more research was needed to develop a fatality model.
They found that the number of fatalities was related to the hydraulic characteristics of the flood and topography; they also found that problems in modelling arose from a lack of insight into the cause of drowning and the interdependency of variables.

The authors consider three scenarios of flood fatality models: dam break, polder or dyke breach and riverine flooding. The factors that determine the loss rate include:

- rate of rise of floodwater;
- warning time for evacuation;
- exposure of people, were they inside or outside a building when flood waters arrived?
- problems of a dyke breach near a residential area;
- depth of floodwater; and
- velocity of water.

The authors cite studies by

- Waarts (1992) who derived relationships between water depth and mortality and the fraction of the inhabitants of the area drowned based on the 1953 North Sea storm surge that devastated the South West of Holland and caused 1,800 deaths. (These relationships are not considered relevant as warning systems have improved since 1953, Jonkman et al).

- Graham (1999) into the loss of life by dam failure using criteria for flood depth, product of velocity and depth and warning time, and flood experience. Graham suggested fatality rates for the following parameters:
  - Flood severity (high, medium and low);
  - Warning time in minutes (no warning, 15 to 60 minutes, and more than 60 minutes);
  - Flood severity understanding (vague or precise);

with values of between 0.3 to 1.0 for the worst scenario, and from 0.0 to 0.0004 for the best scenario; (a fatality rate of 0.0004 means 4 deaths per 10,000 people exposed to risk).

- Abt et al developed a relationship between product of velocity and depth, person weight and height for the instability of people in flood flows for persons exposed to advancing floodwaters. It is not stated whether the above relationship holds for people who might be indoors during the advancing flood wave.

\[
P.N. = 0.0929[e^{0.022(2.2G+L/25.4)+1.09}]^2
\]

Where

- P.N. product number of stream velocity and water depth (m\(^2\)/s)
- G weight of person (kg)
- L length of person (m)

Jonkman et al also discuss other models, tabulate the comparisons and concluded that no existing loss of life model could be used with any certainty due to the complex exposure and environmental conditions that effect modelling parameters.

So then, how might the above be applied to the Yangtze River situation? In the Yangtze River detention basins, people will be evacuated from a detention basin before a planned...
flooding so the total exposed population for which fatality rate would be applied will be minimal. For example, if a basin has a population of over 100,000 and the evacuation percentage is say 99.99%, then 10 people would be remain in the basin. Jonkman et al show a graphical relationship (HVK 2000) between rate of rise and flood depth and fatality factor (based on 1953 data and technology). For similar conditions that might exist in a Yangtze River detention basin where depths at about 4 metres and a rate of rise perhaps 0.2 metres per hour would give a fatality rate of say, 0.05. In the example above, possibly 1 of the 10 people remaining in the basin might drown. The key is whether all the population can be evacuated. Advice from local flood control officers and the fact that evacuation is handled by the PLA supports total evacuation.

However, should an emergency arise and full and careful evacuation be not possible, then the chance of injury or fatality would be high.
PROPOSED METHODOLOGY

The foregoing literature review outlines common flood damage assessment practices in China and to some extent makes comparisons within practices in Australia and the United States. How this information can be used will depend on the data available that can be found or applied to each of the 40 detention basins that might be deliberately flooded during a major flood event.

The elements of flood damage assessment will include estimates of the assets at risk; loss rates applicable for warning time, depth and duration of flooding; and classified into direct and indirect costs. Also of advantage could be a knowledge the simpler impacts of lost opportunities expressed in monetary units per month of expected inundation.

The literature review has also touched on the social impacts of flooding. The following methodology outlines how social statistics can be applied to develop a Social Impact Index Procedure.

Flood Damage Estimation Procedure

Data availability

Qianliang Hu detention basin

Actual flood losses are available by land use type, crop losses, buildings destroyed and infrastructure damaged for the 1996 flooding of Qianliang Hu detention basin. This information indicated damage by category, number of units affected and costs in monetary terms.

GIS information is available in ArcInfo format that accurately depicts the geographic boundaries of the basins that comprise the Qianliang Hu detention area. GIS data are accompanied by instructions from Hunan Province for table use and the codes used for each feature. The GIS can also be used to count the number of buildings, provide building footprints, determine gross urban and aquaculture areas and by extension, agricultural areas.

Also available are Provincial statistical yearbooks (Hubei 2002 and Hunan 2002) that contain economic, social and agricultural statistics for the Province and for Huarong County in which Qianliang Hu basin is located.

Jingjiang detention basin

The Jingjiang detention basin is one of the largest basins and being adjacent to the Yangtze River is most effective in reducing peak water levels. When this basin was first (and only occasion) flooded in 1952 water levels in the Yangtze River dropped by 76 cm, (pers. comm. Huarong County flood management officials). The basin is also on the opposite bank to the important city of Shashi.

Being so effective it has been the subject of a number of floods studies, including flood damage assessments by the European Union – Sino ANFAS project. Asset data for this study was derived by remote sensing (satellite based photographic and radar imaging).
Also available (and being sought at the time of writing) is GIS data at 1:250,000 scale. Other information is held by the Yangtze Scientific Research Institute (within CWRC).

All detention basins

Information that is available for all detention basins includes:
- GIS data on location and area;
- Tabular information on basin area, flood storage capacity, population, and area under agriculture;
- Flood height information within the hydro-meteorological database that will indicate flood plain gradients (roughly equivalent to hydraulic gradients); and
- Social, agricultural, commercial, industrial, and economic statistics by county within each Province.

Estimation of assets at risk

Given the foregoing, exceptional detail exists at the micro-scale level for Qianliang Hu detention basin. The detail for Jingjiang detention basin is expected to be more limited but will be supplemented by complementary macro scale data. Common to all basins will be information on area, flood storage volume, water levels, population and statistical yearbook information.

Under Chinese policy, commercial and industrial production is prohibited in sacrificial detention basins and only agricultural and social activities are permitted. Housing of agricultural workers is usually of fired red brick construction. Schools are usually well equipped but medical facilities are limited to clinics; hospitals are located in high priority protection polders.

Given common types of development and human activity in all detention basins, it should be possible to estimate the number and type of assets for each basin as a ratio of known facts such as basin area, agricultural area, population and flood volume. Preliminary work indicates that:

- Lengths of road can be related to area;
- Road type lengths can be estimated from known GIS information of road hierarchy;
- Lengths of high voltage transmission lines can be related to area;
- Lengths of low voltage power lines can be related to population and area;
- The number of dwellings can be estimated from population;
- The number and type of schools can be estimated from population and county statistics;
- The area of fish ponds can be estimated by GIS and cross referenced to yearbook information;
- Known agricultural area can be split into areas by planting and crop yields for yearbook information.

These estimates of assets at risk will then be compared with known losses from the 1996 Qianliang Hu flooding and estimated losses from other Jingjiang studies. Some discrepancies are expected given the intervening period.
To summarise, if the assets at risk can be estimated from a few known parameters using the ratio method and then proven for two significant basins and all basins are similar in character, then flood damages should be able to be estimated for all basins with limited data. Given that the purpose of the estimates is to illustrate comparative impacts of flood control decisions the methodology seems appropriate.

**Unit costs of flooding**

Unit costs of flooding can be derived from the 1996 damage statistics of Qianliang Hu detention basin provided by Hunan Province. These identify assets lost and the value of those losses. The Provincial Statistical Yearbooks (Hunan 2002 and Hubei 2002) also provide annual cost indices, total quantities of production by County and value of that production. These can be compared and unit rates derived.

**Loss rates**

Loss rates for agricultural activities are well documented but comparisons indicate diverse approaches. The loss rates to be chosen will be guided by the authority provided by the literature; commonality of loss rates used in other studies and by the completeness of the documentation of research into all the factors that are used to derive the published loss rates. Furthermore, the loss rate tables that are derived should be as simple as possible to avoid misapplication and ease of coding into a socio-economic impacts estimation computer program. These loss rate tables should also consider the conditions of flooding:

- Duration of flooding of a detention basin will be at least one month to three months;
- Depth of flooding generally at least three metres deep;
- Warning time and flood experience of residents must be considered at least adequate or ample; and
- Time recovery after flooding one to two months depending on whether urban or rural and the duration of inundation.

One author (Mei) raised the joint probability issue of whether the timing of the onset of the flood and the degree of maturity of crops should be considered. In terms of direct loss the answer should be yes. However if the duration of flooding and recovery exceeds three months (as is likely), then only one crop will be harvested instead of three crops in the growing season. So when the direct cost is combined with the opportunity cost, the joint probability issue disappears in practical terms. It must be remembered that the estimates of flood damage for all 40 detention basins are to be calculated explicitly before the flood season and used as a reference in determining which basin or series of basins need to be flooded. If it is assumed there are essentially no flood timing or duration differences between basins, then it is considered that joint probability issues can be safely ignored.

**Potential Concern**

The foregoing assumes that detention basins built on floodplains have uniform ground levels and once flooded, flood depth will be uniform. Unfortunately this is not the case in all basins. For example, the Jingjiang basin is a large elongated basin where the floor level at inflow point is several metres higher than the floor level at outflow. (The basin is roughly parallel to but some distance away from a steep section of the Yangtze River). It also has a narrowing between its western and eastern dykes that provide a constriction during flooding.
The hydraulic fall through this nine kilometre long constriction is over 1.5 metres, (pers. comm. Professor Zhang Xiaofeng, Wuhan University).

However when the depth of flooding is over three metres for several weeks and depths can reach six metres or more, the impacts of the basin floor gradient should be able to be safely ignored. Nevertheless, each basin will have to be examined to ensure basin floor gradient is not an issue.

**Indirect losses**

Indirect costs will be incurred to all sectors of the economy as well as impose additional burdens on emergency activities and hospitality of evacuated persons following a flood. The literature indicated the following rates have been derived:

- Indirect costs to farming are 28% of direct losses
- Infrastructure are 30% to 50%
- Industrial and commercial are 30%

and will be compared to actual damages for verification.

The costs of emergency response activities have not been found. It must be remembered that the Peoples Liberation Army (PLA) and Chinese Red Cross play a fundamental role and their expenses are not expected to be available. However the costs of food and medical attention for evacuated persons are available within the 1996 Qianliang Hu damage statistics provided by Hunan Province.

The justification for including opportunity costs in the flood damage procedure remains unanswered. The Bureau of Transport and Regional Economics argue that a loss of productivity in one area is picked up by another area and the only real incremental costs are those involved in warehousing and transportation. Given that the purpose of this flood damage estimation procedure is to determine the comparative impacts of flooding detention basins, there seems little point in trying to calculate opportunity costs.

**Social Impact Index Procedure**

A social impacts index procedure can be developed using a similar methodology to the flood damage procedure. In its simplest form, the elements of human activity can be listed, counts provided and a subjective “social weighting” applied to each score. The scores for each basin are totalled and can be compared to achieve a relative impact index.

In the following table (work in progress), the “weights” are examples only and have valid justification for their use. The determination of weights will be subject to a future workshop. The index is heavily biased to population statistics and it could be argued that population should be used as the prime indicator. However this does not take into account the relative importance to the community of the various age groups and activities that make up the social fabric of a community.
### People

<table>
<thead>
<tr>
<th>People</th>
<th>Count</th>
<th>Ratio</th>
<th>Ratio of</th>
<th>Weight</th>
<th>Score</th>
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<tr>
<td>Population residing:</td>
<td>67,400</td>
<td>Known</td>
<td>1</td>
<td>67,400</td>
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</tr>
<tr>
<td>Urban popn:</td>
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<td>0.26</td>
<td>Popn County</td>
<td>0.5</td>
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<td>Workers from outside:</td>
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<td>Popn County</td>
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<td>3.93</td>
<td>people /house</td>
<td>2</td>
<td>84,587</td>
</tr>
<tr>
<td>Resettled:</td>
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<td>% population</td>
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<td>0</td>
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<td>Estimated fatalities</td>
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<td>Estimated injuries</td>
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### Statistics

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<th>Weight</th>
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<td>3.93</td>
<td>people per house</td>
<td>2</td>
<td>34,300</td>
</tr>
<tr>
<td>Other buildings:</td>
<td></td>
<td></td>
<td>Inferred</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Administrative properties:</td>
<td></td>
<td></td>
<td>Counted</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Commercial properties:</td>
<td>6</td>
<td></td>
<td>Counted</td>
<td>25</td>
<td>150</td>
</tr>
<tr>
<td>Villages:</td>
<td></td>
<td></td>
<td>Counted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial properties:</td>
<td>0</td>
<td></td>
<td></td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Hospitals:</td>
<td>2</td>
<td>29,842</td>
<td>Popn County</td>
<td>1000</td>
<td>2,259</td>
</tr>
<tr>
<td>Health care institutions:</td>
<td>3</td>
<td>20,463</td>
<td>Popn County</td>
<td>500</td>
<td>1,647</td>
</tr>
<tr>
<td>Schools:</td>
<td>31</td>
<td>357</td>
<td>per enrollments</td>
<td>500</td>
<td>15,481</td>
</tr>
<tr>
<td>Houses demolished:</td>
<td>10,762</td>
<td>0.502</td>
<td>No Houses</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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CONCLUSIONS

The literature review has found that there is sufficient information contained in recent Chinese publications to develop socio-economic impacts assessments procedures. These procedures can be applied to detention basins using a few known parameters such as basin area, agricultural area, population, flood storage volume and depth and duration of inundation for the purposes of comparing the relative impacts of flooding.

This medium scale of application can be verified using micro-scale data available for two major detention basins. Micro scale flood loss rates are supported by recent studies on various parts of China.

Intangible flood damage can be expressed as a percentage of the direct loss and similar rates apply to both China and Australia.

Very little work has been done to quantify the social impacts of flooding but sufficient information is available to develop a social impacts index procedure so that comparisons can be made between basins. This methodology relies on the use of “weights” for each parameter that are subjective in nature. Whatever weights are chosen will depend on the nature of the group making the assessment. However once chosen, the weights can be applied to all basins.
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REFERENCES


