**Modern irrigation technics, Maliki, Afghanistan, 1991.** *A. Donini*

stretches of the river, including reaches used for recreation and the habitat of endangered species. They may also be dangerous; about twenty major dams collapse somewhere in the world each decade. In more densely populated countries, such as in Europe, it is difficult to find space for the large storage required and this solution has found less favour. In place of a large reservoir on the main stem of the river, the use of several smaller storages on tributaries is often advocated. There may be cost advantages in this approach and the different reservoirs may be built one after the other, on the instalment plan, making financing easier. There are hydraulic advantages in that floods would be caught nearer the source, but on the other hand any floods due to rainfall downstream of the tributary reservoir would not be controlled. An extreme version of this approach that is often advocated is to use a very large number of cheap structures in the headwaters that could also provide farm water storage for stock watering or small irrigation purposes. These "farm dams" are commonly used in many parts of the world at the extreme upper end of tributaries, even before a real stream has developed, and provide water storage for the farm and impede direct runoff, which helps to reduce floods at source. The number of dams required for effective flood control would be large and similar storages would need to be provided in non-farm areas, such as forests. The idea is hydrologically attractive as excess runoff would be controlled at source, but there is as yet little experience in the large-scale use of many small storages for flood control.

## Flood detention basins

These small basins are also known as balancing basins. They are typically built to reduce the effect of rapid runoff from the paved streets and roofs in towns and cities. The storm water drains from an urban area would typically discharge into a local stream, but before the drain reaches the stream a detention basin may be built to delay the flood flow and to release it more gradually into the receiving stream. Usually the basins are built very simply with a small uncontrolled outlet that will restrict the outflow sufficiently to avoid flooding downstream. As noted previously, urban runoff often contains great amounts of sediment and the basin also allows this to settle out. Minimal maintenance is required to ensure that the outlet is not blocked and from time to time, particularly after large storms, the sediment may have to be cleared. Sometimes the basin may form a water feature in a park, and in other cases it may be possible to build it in a gully that would otherwise be unused. It may be necessary to fence the basin as a safety measure to prevent people being drowned in a flood. These are very cheap structures that are usually designed using a simple rule relating the basin capacity and outlet size to the urban area being drained. In many countries urban developers are required to provide these detention basins to balance the effects of increased runoff from their developments.

China uses extremely large detention basins to absorb floods on its major rivers. At Zhengzhou the Yellow river leaves the mountains and crosses the plain towards the sea. This plain has been subject to flooding since time immemorial. Large flood detention areas have been designated on the plain to protect the rest of the plain. People live in these areas, one has a population of 250,000 and 1,000,000 live in the other. When a flood requiring the use of the basin is expected these large populations have to be evacuated.

## River training

River training is the improvement of the river channel to enable it to evacuate flood waters more quickly and to enable it to carry a flood flow at lower depth. The improvement may take the form of deepening, widening or straightening the channel. Alternatively, a special flood diversion channel may be built to carry high flows either around a location to be protected or out of the river basin entirely. River training may have a number of other benefits which can be realized at the same time. For example, the natural movement of river meanders may be threatening some installation and stabilization of the meanders could be combined with increasing the flood-carrying capacity of the river channel. Improvement of navigation by deepening, straightening or stabilizing the channel is also often combined with flood alleviation works. River training will usually be accompanied by constructing dykes to define the river channel.

For high value locations, such as a large city, a diversion channel can be an economical means of flood protection. Winnipeg, the capital of the Province of Manitoba in Canada, lies at the junction of the north-flowing Red River and the east-flowing Assinboine River. The earliest flood protection provided was in the form of dykes along the Assinboine River late last century, but these resulted in sediment being deposited in the river channel, raising the channel bed above the surrounding flood plain. The dykes were generally low and could not contain a major flood. As well as the dykes, cut-off channels were built on some of the sharper river bends to improve the flow capacity. A very severe flood in

Flood damage, Philippines.
*Still Pictures: N. Dickinson*

Houses collapsed. Besieged victims waiting for rescue. *China News Agency*

the existing channel meanders, while still allowing flood flows to use the full width of the meander belt. The river was already dyked on both sides of the meander belt and the solution adopted was to build further low dykes inside the meander loops. These would cause low flood flows to follow the meandering channel more closely, but during higher floods they would be overtopped, allowing the river to take a more direct course, but with some flow still being directed down the channel to keep the sediment moving. The dykes had to designed to withstand overtopping and, as usual, construction costs had to be kept low. Fortunately, a source of very large boulders was available at not too great a distance and the dykes were built from these large boulders, which model tests showed would withstand the flood flows. The dykes formed a series of wide spillways that controlled the high river flows and allowed flow directly down slope with complete safety. A large hydraulic model of the complete meander zone was built to investigate the detailed design and placement of the new dykes and smaller models were built to investigate the flow over the dykes to ensure they would not be eroded.

In both these large river training works care was taken to work with the natural forces shaping the river system so that the river was controlled without serious side-effects and at low cost.