THE PO RIVER – 2000 YEARS OF LESSONS

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Abstract

The Po River is Italy's longest river at 650 kilometres with a 70,000 square kilometre catchment. More than 18 million people live and work on the Po River floodplain and about 50% of it is cultivated.

The floodplain's fertility is what initially attracted people there thousands of years ago and it remains some of the most heavily cultivated land in Europe. Major cities sprang up, and since the Second World War in particular, they have become major manufacturing centres in Italy's highly industrialised economy. Other cities and towns retain their rich cultural heritage and historic beauty.

Each autumn, the Po River floods and the valley suffered devastating floods in 589, 1438, and 1951. For hundreds of years people have tried to reduce flood damages with constructed levees which now line more than half its length. These have created problems of their own.

This paper gives a brief overview of what Italy is doing in the 21st Century to manage the Po River floodplain. Despite cultural, climatic and historical differences, many of the lessons the Italians have learned are relevant to floodplain management in Australia

Key Words: Po River; floodplain management, levees, urban planning, response planning, evacuation

Introduction

While visiting the Po Valley, I took the opportunity to contact authorities involved in floodplain management. Due to the holiday season, some key people were not available. Nevertheless, people from the Italian Red Cross, Il Magistrato di Po and Parma University provided useful insights.

Some of the information provided was outside of the specialist knowledge of those with whom I met. The information in this paper therefore should not be relied upon as providing definitive data about flooding, development or policy in the Po Valley.

Rather, it provides a general overview of contemporary floodplain management in the context of the river's rich history.

Geography

Topography

The Po River is Italy's longest river at 650 kilometres and is fed by 141 tributaries. It has a 70,000 square kilometre catchment stretching across northern Italy from the French border on the west to the Adriatic Sea on the east (see map in Appendix A).

The river's complex delta protrudes into the sea about 60 kilometres south of Venice.

The Po's source is in French Alps near Monviso (3,841m). The Alps on the Swiss and Austrian borders to the north include some of Italy's highest peaks and rise to over 4,000m. Here there are many glacial lakes through which the Po's tributaries flow before passing through foothills of glacial moraine

and joining the river on the floodplain. Some of these northern tributaries are over 200 kilometres long.

The Apennines form the southern catchment boundary. These mountains are not nearly as high as the Alps and tributaries here can be as short as 50km.

Climate

Northern Italy has hot dry summers, cold winters and its heaviest precipitation in the autumn months of October and November. In winter, most precipitation in the mountains falls as snow and spring rains add to snow melts.

For the whole of Italy the average annual precipitation is 600mm per annum. While rainfall is generally higher in the north of the country than the south, catchment specific data was not available at the time of writing.

Nature of Flooding

Table 1 shows the average flow rate at the mouth of the Po for each month and also the annual average flow. October and November have pronounced peaks with a secondary peak in May during the major snowmelt. October and November are generally the months in which major flooding is most likely to occur.

Flash flooding occurs in the high mountain streams but further downstream the river and its tributaries are less steep and the times of concentration are longer.

There is a distinct difference between the flooding in the northern and southern parts of the catchment.

In the north, the numerous lakes, which have been carved out by ancient glaciers, attenuate the flow out of the mountains before it flows through the extensive foothills and onto the main floodplain of the Po.

To the south the “torrents”, as they are called, drop quickly from the mountains and onto the plains where they run in parallel paths toward the Po. The time of concentration from mountain peak to the Po River can be as little as 10 hours along these tributaries.

Table 1: Po River Average Flow Rates

Month	Flow rates (m3/s)
January	1439
February	1192
March	1290
April	1366
May	1906
June	1680
July	1047
August	781
September	1398
October	2616
November	2291
December	1566
Annual average	**1547**

Source: http://www.adbpo.it/

River Morphology

The Po River carries a very high bed load of sand and gravel from the glacial moraine at the foot of the Alps. Each year there can be a significant shift in the river course and the bed profile following the autumn flows.

The main river channel varies in width from a couple of hundred metres to several hundred metres. The main floodplain is up to 30 kilometres wide. In the Po Delta there are numerous anabranches which have appeared and closed over the centuries.

History

To understand contemporary floodplain management in Italy it is necessary to understand the history of the country as well as the history of flooding and of development.

Governance

For the majority of its history, the Po Valley has been divided between independent principalities, city states and empires.

It has only been since the unification of Italy in 1861, that the whole of the Po floodplain has been under a centralised government.

In 1946, Italy became a democratic republic. In addition to the national government, Italy has 21 regions with their own presidents.

Within each region there are several provinces each headed by a Prefect. Each province has a major city with a population of a few hundred thousand.

Within the provinces there are many municipalities each headed by a mayor.

Development

The floodplain's fertility is what initially attracted people there thousands of years ago and it remains some of the most heavily cultivated land in Europe.

There are over 5 million pigs and 4 million cattle as well as other livestock living on the floodplain. They are virtually all kept in stables year round.

As the population grew, villages sprang up. During the last millennium many of these developed into major cities which are centres of learning, art, and science.

Despite its rich cultural history, Italy remained a predominantly agricultural society until after the Second World War. From the 1950s to the 1970s it became one of the world's "Miracle Economies" and a world leader in design, manufacture and food processing. Its citizens now enjoy a standard of living similar to Australia.

The cities and towns of the Po Valley capitalised most on the post war economic growth and many, including Milan, have become major manufacturing centres in Italy's highly industrialised economy. Other cities and towns retain their rich cultural heritage and historic beauty and have significant tourist trade.

Over 18 million people now live and work in the catchment. This is nearly a third of all Italians. While the catchment accounts for less than 25% of Italy's land it is responsible for more than 50% of its economic output (http://www.magma.nationalgeographic.com/)

The river's alluvium is also an important source of sand and gravel. More than 20 million cubic metres are extracted annually, principally to make concrete.

Housing

Recent archaeological discoveries show that prehistoric inhabitants of the Po lived in timber houses built on stilts perhaps in response to the seasonal river flooding.

Better technology resulted in stone or brick construction providing greater insulation from cold winters and hot summers. Today, the majority of dwellings are of concrete and brick construction.

The majority of the population live in apartments of three or more storeys. Single storey dwellings are virtually non-existent and what appear to be freestanding houses are often small apartment blocks with nuclear families of the same extended family living in each apartment.

Most dwellings have tile flooring or, as a more modern trend, parquetry. Wall to wall carpets are virtually unknown.

Flooding

Literature suggests that the Po suffered significant floods in 589 and 1438. It is known that in the 11th Century Como and Maggiore lakes in the northern Alps had very large floods which entered lakeside towns. Many of the major cities have recorded floods over the centuries.

However, despite the long history of settlement and flooding in the Po Valley, it is only in that last 200 years that useful rainfall, flood or flow data has been collected to assist hydrologists in modelling floods, flows and frequencies.

Furthermore, the changing nature of the river, catchment development and, most importantly, levee construction has made it difficult for hydrologists to apply historical flood level data to the contemporary river and floodplain.

Better data has been collected since the 1920's and accurate and extensive data since the Second World War.

Despite this paucity of data, researchers at Parma University have been able to successfully model the flooding which occurred from levee breaks in 1872, 1879 and 1893 (http://www.extenza-eps.com/). These caused devastating flooding of up to several metres depth in the vicinity of Bologna over floodplains of 500-600 km^2. Some of these floods were estimated to have a about a 1 in 200 AEP.

Levee failures in 1951 at numerous locations along the Po turned a flood with about a 1 in 50 AEP into a catastrophe with about 1,000 fatalities. More than 1,100 square kilometres were flooded and over 200,000 people displaced.

In 1994, a similar sized flood occurred when 300mm fell in two days. Nearly 70 people were killed in that flood due mainly to failures in the flood warning system.

In 2000, there was a flood approaching a 1 in 100 AEP event. Accurate, real-time flood forecasting, precautionary evacuation of tens of thousands of people and levee reinforcement during the flood prevented a disaster.

Nevertheless there were 15 deaths, dozens of bridges destroyed and 173 road closures.

In Turin (pop. 1 million), the main street was under half a metre of water, all schools were closed, 30,000 people were without electricity and some districts were without water (http://www.edition.cnn.com/). Fiat closed three of its largest manufacturing plants and many other businesses were evacuated or forced to close.

Floodplain Management

Apart from the prehistoric pole house, the earliest records of floodplain management on the Po date from the 11th Century when the first of the argini (levees) were known to be built along the main river (no more than a couple of metres high).

During successive centuries there were localised extensions to these low levees. During this period, many of the major cities formalised the Po's tributaries where they passed through the city.

Nevertheless, it was not until the time of Napoleon Bonaparte that construction of an extensive system of levees was commenced along the Po to provide better protection from larger floods. This was made possible by the fact that his military dictatorship and that of his successors extended along the entire length of the river.

Sporadic levee work then occurred in the 1870s mainly in response to the devastating floods at that time.

Further extensive work was not undertaken until the valley was again under a military dictatorship when Mussolini directed civil works programs in the 1920s and 1930s.

Following the devastating floods in 1951, the relatively young democratic republic was galvanised into action to think strategically about floodplain management.

Initially, this involved the creation of Il Magistrato di Po in 1956. This was an inter-

regional authority charged with responsibility for designing, building and maintaining the system of levees and later developing a flood modelling, forecasting and warning system.

In the 1980s, as a result of more sophisticated flood modelling, it was realised that simply undertaking engineering works was not sufficient to manage the magnitude of the Po's potential flooding problems.

Protezione Civile, was given responsibility for developing detailed flood response and evacuation plans.

In 1989, l'Autorità di Bacino del Fiume Po (the Po River Basin Authority) was created to integrate urban and resource planning with flood management.

The Authority is currently developing a management plan for future development and redevelopment across the entire catchment and has interim development guidelines.

The 1994 and 2000 floods caused all of the above organisations to review their policies, plans and works.

Contemporary Floodplain Management

Flood Modelling

Il Magistrato di Po has hundreds of pluviometers and hydrometers throughout the catchment. Data from these feed a real-time flood forecasting model. It is able to forecast flood peaks up to 72 hours in advance but with a low level of accuracy. Forecasts within 24 hours of the peak can be quite accurate despite the fact that the significant annual changes in bed and bank conditions mean that new topographic surveys are required every three years.

In 2000, the model's flood forecasts were generally correct to within half a metre and were used to issue warnings, plan evacuations and direct levee reinforcement.

Flood Controls

The levees remain the primary defence against flooding. There are three types.

The Argini Maestri (master levees) provide the highest level of protection along the main river channel. These can be constructed up to two or three kilometres back from the channel but often line the riverbank.

Since the 2000 flood there has been a program to increase the height of all of these levees to half a metre above the 1 in 200 AEP level. This is about equivalent to a 1 in 500 AEP peak and was chosen as a suitable compromise between cost and avoided flood damages. More than half the river's length is lined on both sides with master levees which can be several metres high.

Tributary levees are the second type of protection. They are either built to the height of the master levees or, where the mouth of the tributary is small, flood gates are installed and the tributary levees need only be built above the tributary's 1 in 200 AEP peak if practical.

The lowest level of protection is provided by smaller levees which are constructed on river terraces between the river channel and the master levees. By law, these now must be at least one metre lower than the master levees and the majority are only two or three metres high. The area between the minor and master levees is called the "golena".

The master levees are owned and maintained by Il Magistrato di Po. The smaller levees are either privately owned and maintained or are the responsibility of the local council.

The long history of levee construction and raising means that in many locations the quality of levees were poor. Many of the levee failures in the 1800s and also 1951 were due to piping failure or toe erosion.

Concrete curtain grouting has been used recently to reduce master levee permeability in places.

Confining a 30 km floodplain to 3 or 4 km means that flood peaks and velocities are now much greater than they would have been naturally.

Furthermore, there are now areas along the river which are confined by the master levee of the Po on one side and tributary levees on the other two sides. Should a levee fail the entire river can pour into this confined area (albeit a few hundred square kilometres) and fill it to a depth of several metres within a day.

On the tributaries to the north there are outlet controls on some of the lakes. Exercising these outlets can involve a compromise between inundating lakeside towns upstream or riverside towns downstream.

Il Magistrato di Po is purchasing land on some tributaries to create off-stream detention basins. With capacities between 10 and 20 million m^3, they will reduce flood peaks on the tributaries but are not big enough to significantly impact on levels in the Po. They will inevitably increase flood duration which increases the chance of piping failure of levees.

Urban and Resource Planning

Until recently, flooding was not a formal consideration in urban or resource planning. While major cities, towns and industrial development are generally outside the master levees, this is not always the case.

There are many farmhouses and small settlements and even some industrial development and major infrastructure within the golenas. Predominantly, however, the golenas are used for agriculture.

Sand and gravel extraction is common within the main channel and processing plants are generally within the golenas.

The terraces immediately adjacent to the main river channel are also often used for poplar plantations.

Italians do not move house as frequently as Australians and it is quite common to find families that have lived on the same property for generations, particularly in rural areas. This means that there is a reasonably high awareness of flood risk and the fact that the levees do not provide failsafe protection. For this reason, residences within the golenas are much cheaper than those outside of the master levees.

Following the 1994 floods, the national government decided that rather than provide financial aid to people living within the golenas, they would instead reduce the annual land taxes for those properties.

This, combined with the already low property prices has made these dwellings popular with immigrants from Africa, Albania and Southern Italy who have come to the Po Valley seeking work. Now there is an increasing proportion of people living in the highest risk areas that do not appreciate the flood risks.

The interim catchment plan developed by the Autorità di Bacino del Fiume Po, amongst other things, divides the floodplain into three zones for planning purposes. Local government must make development plans consistent with the catchment plan.

Zone A in the plan includes the main river channel and river terraces not protected by levees. In this zone, resource extraction will be permitted if it does not expose levees to erosion risk. Poplar plantations will also be permissible within designated parts of Zone A.

Zone B is within the golenas and may only be used for cultivation, plantations or playing fields. Existing dwelling owners within Zone B can only stay if they can get the local authority to enclose their properties to the height of the master levee without increasing flood levels elsewhere. If not, then they must apply for financial assistance to relocate. The intent is to have all dwellings with less than a 1 in 500 chance of being flooded.

Zone C is the area protected by the master levees. Even in this area there will be development restrictions. It will not be permissible for key infrastructure such as power plants and hazardous industry to be built within this zone.

Standard masonry construction obviates the need for flood resistant building standards. Buildings generally withstand several metres flood depth but can take several months to

dry out, particularly in the cold weather following the autumn floods.

Emergency Planning and Response

Italy's Protezione Civile is a national organisation with professional staff and volunteers throughout the country. It has developed or is developing detailed flood response and evacuation plans in association with Autorità di Bacino del Fiume Po for all flood prone areas in the catchment. These include details of all dwellings within the golenas including the number of people, their age and infirmities.

On the tributaries there can be less than an hour's warning of flooding but along the Po there can be several days' warning.

Evacuation is prioritised with children and the infirmed being evacuated first, followed by business and industry and then, finally any remaining residents. There is also prioritisation based on chance of levee failure and proximity to levees.

The plans include the systematic breaching of minor levees when it is forecast that they would overtop and flood the golenas. This reduces the risk of sudden failure and keeps the river level low for as long as possible.

Levee breaching and evacuation decisions are the responsibility of the Provincial Prefect in minor floods and the Minister for the Interior in major floods. Both rely upon information provided by Il Magistrato and Protezione Civile.

Protezione Civile co-ordinates all flood response actions with assistance from the police, Red Cross, Fire Brigade, Il Magistrato di Po and the army.

There are penalties, including imprisonment, for anyone who does not follow the directions (including evacuation orders) of Protezione Civile during a flood.

Conclusion

Despite climatic and cultural differences and a longer flooding and levee construction history, floodplain management evolution in the Po Valley over the last 50 years has paralleled that in Australia in many ways including:

- Systematic levee construction co-ordinated by a single authority following devastating floods in the 1950s.
- Better flood modelling, forecasting and warning in the early 1980s through improved computing techniques.
- More sophisticated emergency preparedness and response planning and development control planning since the early 1990s.

The principal differences to Australia are:

- The Po River floods every autumn
- Levees are used as the main flood defence
- The Italians have decided that dwellings, livestock or industrial development should have less than a 1 in 500 chance of being flooded in any year
- No further key industrial development will be permitted below the PMF
- There are penalties for failing to follow evacuation orders.

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References

Agnetti A, Aureli F, Mignosa P, Scenari Di (2002) “Allagamento Conseguenti a Crollo Arginale nell’Oltrepo Mantovano” *Estratto del’ Acqua* 5/2002 Associazione Idrotecnica Italiana September October 2002.

http://www.adbpo.it/

http://www.extenza-eps.com/

http://www.edition.cnn.com/2000/world/europe

http://www.magma.nationalgeographic.com/

Appendix A

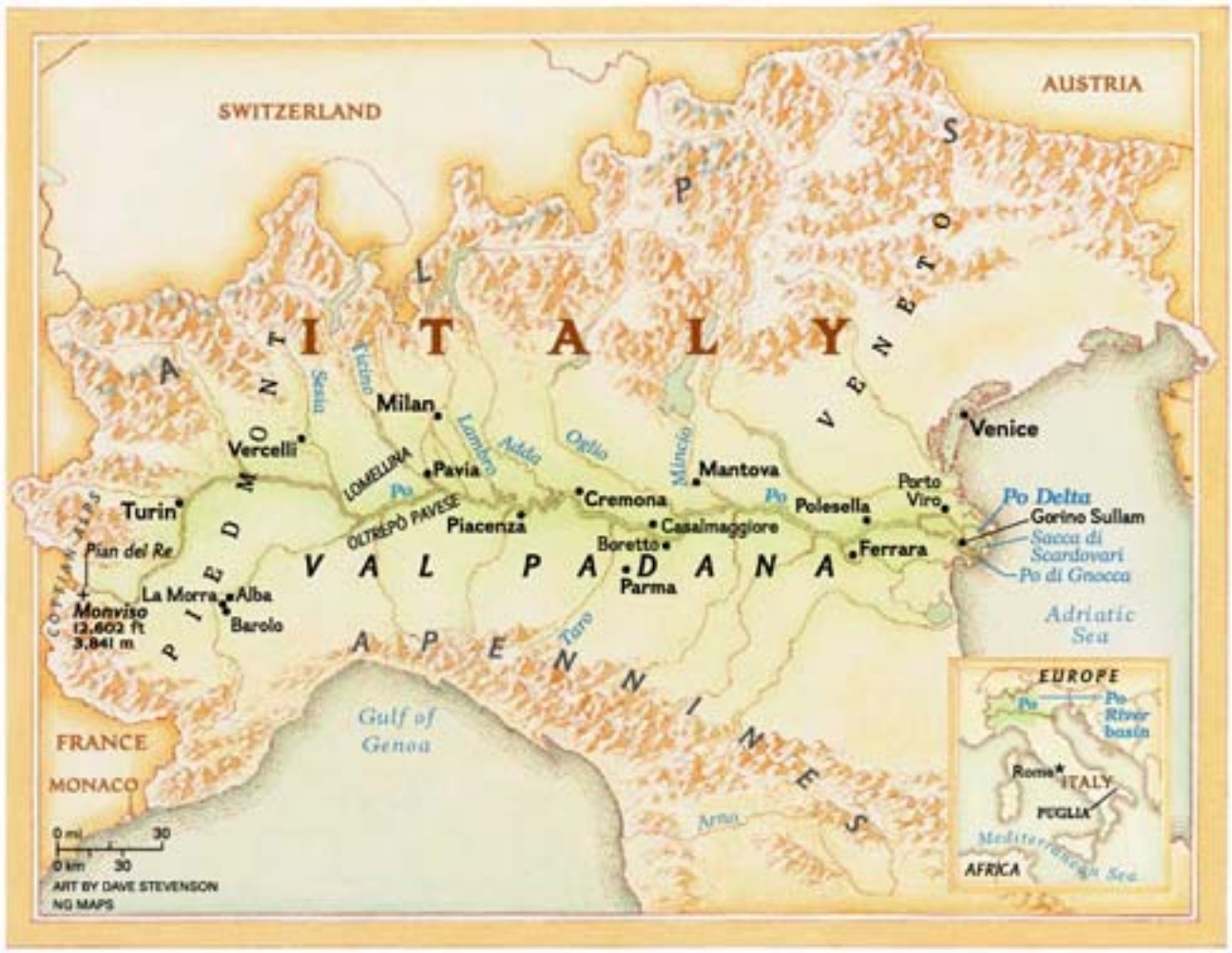

Figure 1: The Po River Valley (Val Padana)

Source: www.magma.nationalgeographic.com

Author Biography

Steven Molino has spent a substantial part of the last decade investigating flood damages, mitigation and flood preparedness.

He led investigations into flood impacts on the Hawkesbury Nepean as project manager for the Warragamba Dam Safety EISs. Subsequently, he provided expert advice to the Hawkesbury Nepean Flood Management Advisory Committee on the effects of flooding on communities and infrastructure.

He prepared a flood preparedness strategy for the Woronora River and has investigated flood warning technologies for the NSW State Emergency Service. He has also project managed the design, implementation and evaluation of numerous community education projects drawing together his own technical expertise and the communications and education expertise of his staff.

His knowledge of flood preparedness and evacuation planning has been used in independent reviews of the life safety risks of several significant developments. He has also advised State Water on dam safety issues and has presented at Emergency Management Australia's community education course. He is the editor of the recently launched Floodplain Manager newsletter.

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