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Call it A 'Wash'? Historical Perspectives on Conundrums of Technological Modernization, Flood Amelioration and Disasters in Modern Japan 「チャラ」とでも言おうか　歴史的視点から観た近代日本の技術近代化、洪水対策、災害の難問

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3.11 + 3: Special Issue on Japan's Triple Disaster Three Years On

Abstract: The Northeast Japan triple disasters have raised questions about the adequacy of government planning for water damage at Fukushima, yet other components of the built environment also contributed to loss of property and life in unanticipated ways. Such "surprises" associated with large-scale construction have a long history. To illustrate, in addition to exploring ways in which the built environment shaped the tsunami's impact, I examine negative consequences from the construction of the Okotsu Diversion Channel (Niigata). Through the example of a major flood in Tochio (Niigata), I show unexpected links to a government policy, the Meiji Land Tax Reforms, that did not deal with water control at all.

Keywords: Tsunami, civil engineering, Meiji land tax reform, deforestation, built environments, Niigata region, Fukushima nuclear power plants

A close look at videos of northeast Japan on March 11, 2011, reveals that amid the flooding of farmlands, residential districts and business centers, as water traveled inland from the coastline it often followed man-made cement channels that dramatically transformed water flow. Many channel walls were built high above the normal river flow, even towering over the adjoining lands. Such encasements may have protected shoreline districts temporarily but they also generated greater fury than would otherwise have been the case.[1] These were not the only elements of human construction that shaped the impact of the tsunami – the elevated beds for express trains and super highways, through which conduits provided adequate escape for surplus water under normal circumstances, became dams that reduced the drainage of tsunami waters and created long-standing pools of fetid, polluted water – but they represent one important sign of unanticipated consequences of projects designed to protect human populations from the risks of natural events. Despite the sense among Japanese today (and many non-Japanese) that Japan lives harmoniously with nature, multiple cases in both pre-war and post-war Japan argue to the contrary, even in pre-modern times.

In the discussion that follows, I first elaborate further impacts of the built environment on the Tohoku disaster, and then move to brief discussions of two historical examples of other kinds of unanticipated outcomes, one that arose from another attempt to control natural forces and one more that represents a failure to understand the ways in which local hamlets had employed strategies for managing elements of the environment to ameliorate floods. The development of the Okōtsu Diversion Channel in the early twentieth century constitutes the first case. The second is

The Great Tochio Flood, approximately contemporaneous with Okōtsu. Both cases treat problems of too much water, problems that parallel the consequences of tsunami. Both are located in Niigata Prefecture in the lower reaches of Japan's longest river, the Shinano. The former reveals a pattern of government prominence in funding large-scale projects and central oversight of them, a pattern that marks post-World War II developments (including, of course, nuclear energy), too. The latter examines impacts of non-engineering policies on flood risk. In very different ways these cases provide examples of long-term unintended consequences of programs designed to solve one set of issues without awareness of links between the problem area and other systems. Partly as an introduction to these cases, but also as a way of sketching some of the siting issues associated with nuclear plant construction, I present geological and climatic background. I begin with Japanese geography's distinctive characteristics that make it particularly subject to clashes between society and nature, and then turn to the Echigo Plain in particular.

The discussion below demonstrates that it is not simply the built environment that provides opportunities for unanticipated consequences and room to exercise a narrow vision of problem solving. Technologies other than civil engineering, such as the tax system discussed below, can also pack surprises. Whether a "hard" civil engineering technology or a "soft," intellectual one, designers often focus on one problem or set of problems without attention to the broad array of social or environmental contexts in which they function and within which they must operate. While we most often think of those who argue for civil engineering projects – power companies, developers, farmers – as focusing just on their own interests, the same issues arise in the creation of socio-political institutions and policies that serve interests not directly aimed at manipulating the environment but that nonetheless increase risk of calamitous events like floods and landslides.

"Narrowness" of problem-solving vision stems from two sources. One, of course, is human judgment about the range of potential outcomes. For example, thinking only about one segment of a drainage system rather than upstream or downstream impacts in considering a water pollution problem. In such instances, the specific interest groups -- power companies, real estate developers, farmers, individual government bureaucracies – simply think in terms of their own priorities, and presume no, or limited, broad effects unless confronted by other interests aware of links to other environmental or social systems. I mention large groups here simply for illustrative purposes, each can not be presumed to comprise a unified whole: government ministries and bureaucracies may hold conflicting missions (e.g., the Ministry of Agriculture as opposed to the Ministry of Land, Infrastructure, Transport and Tourism), and farm communities may be split based on crops grown or farm location on streams. Among professions on whom planners rely, their disciplinary perspectives (engineering vs. ecologists, for example) may play a role in shaping values and conclusions. Brought together in conversation, some narrowness of vision can be eliminated, but reliance on technical experts alone may still leave many potential ramifications unexplored.

The other source of surprises lies with "the unknown" – factors that, at the time, could not have been discovered or known. This might mean that instruments to detect or measure forces did not exist so risk could not be well identified. Conversely, it might mean that techniques not dependent on instrumentation might not have been developed yet, e.g., the concepts underlying soil mechanics or standardized measures of flood frequency and magnitude ("X-year flood").[2]

When unanticipated repercussions from efforts to control natural forces such as inundation are included in the cost-benefit calculation of these investments, questions arise as to the overall value of the effort. Unanticipated consequences increase overall costs. Even then, one can conclude that across many similar projects, on the whole things work out, but the costs of an individual project may increase substantially.[3] Such a conclusion will still be small consolation for those who suffer when something unanticipated goes wrong in their neighborhood. Nonetheless, we find broad evidence for the triumph of the interests of the few or the benefit to the national economy at the expense of ordinary folk, especially in the rural and poorer areas of Japan.[4]

The Built Environment and the 3-11 Tsunami

Cement transformed the Tohoku tsunami. The dynamics of water flow along cement differs from those of natural shorelines to begin with, but the reverse flow of rivers created by the tsunami transformed and magnified widely known problems associated with the use of cement on rivers. Natural soil, rock and vegetation-lined riverbanks absorb the flowing water's energy. These banks have a plasticity that yields somewhat to hydraulic forces. Surface irregularities disrupt water flow.[5] Hard, smooth cement does not share these characteristics. It sustains higher water speeds, even as channels widen downstream to accommodate increased volumes of floodwater from many feeder streams.[6]

The impact of cement on hydraulic forces and that of higher dikes can be found in more typical flooding as water moves downstream, too. To take just one case, in July 2004, in the area south of Niigata city persistent rains soaked the region, causing flooding on the Nakanoshima and Kariyata rivers among others.[7] The installation of a new dike changed the velocity and force of water coursing down one river, causing the collapse of another dike that had not failed since its construction some three centuries earlier. The increased volume of water resulting from higher dikes in other locations contributed to forcing water through the river bed, under the dike until it came out on the other side, generating erosion that collapsed the dike from the outside in.[8]

Cement beds and walls engendered problems for tsunami waters that differed from those of floods like the 2004 Niigata inundation. The tsunami's force was magnified as the ocean water thrust inland into upstream encasements that jammed the waves into a progressively smaller space, increasing its velocity and force. On 3-11 the effect was similar to that of a wind tunnel or tall parallel rows of urban buildings that generate increased wind speeds.

Further, the height of the dikes meant that a greater volume of water was retained in these chutes, and in combination with the increased water velocity, bolstered the stream's carrying capacity. Larger objects were transported farther upstream than would otherwise have been the case. Increased forces hurled objects around in the water with greater energy, generating more lethal danger for any living creature fighting to survive in the maelstrom. At these increased speeds any object the water and debris struck suffered greater damage. When waters finally escaped confinement, they and all that they carried were projected onto the land more violently.

To be sure, we saw the impact of the built environment at the Fukushima power plants, too. Protective walls designed to keep tsunami waters at bay were overwhelmed but did not topple, and as water receded, held floodwaters in. Failing to anticipate flooding of this magnitude and not well protected against this eventuality, backup power facilities failed, impeding reactor cooling.

Civil engineering projects that helped shape the repercussions of the March 11, 2011

Tohoku tsunami extended well beyond those that affected the safety of nuclear power plants *per se* and they encompassed broader dilemmas of water control with which Japan has contended for generations, long before the advent of nuclear power. Flood control projects, including sea walls, were designed to protect and permit the development of lowland areas as free from flooding as possible – flooding which came from one direction only and with which Japan has contended historically. Sea walls were to protect inland areas from the sea; dikes, drainage channels and other inland riparian works were designed to protect lowlands from water flowing downhill in streambeds.

Modern civil engineering projects represent the current end-point of an extended, on-going Japanese tradition of riparian control that has built engineers' and planners' confidence in their efficacy. Indeed, one can argue that their record engendered planners' faith that sea walls would protect the Fukushima nuclear plants from tsunami damage. Riparian control projects, some many years old, others the product of the late twentieth-century boom in public works construction, continue to shape society's vulnerabilities as well as its opportunities. It is typically the latter that claims (laudatory) attention, at least until disaster strikes. Projects such as these have been designed to address a clear problem or small set of problems sensed by society as a whole or some significant segment of it, e.g., residents who want protection from flooding, farmers who want more irrigation, urban planners who seek better drainage to develop potentially valuable urban lands, managers and users of ports who argue for protection against tsunami, or electrical power generation companies that propose to harness hydropower.

It is also clear that designs of major civil engineering projects focus on one or a handful of issues that, even if usefully addressed, often mean ignoring or minimizing other, very problematic risks. In the case of Fukushima, evidence that power plants faced risks of tsunami of historic magnitude (e.g., the 1700 "orphan tsunami") was underplayed.[9] Further, efforts to prevent flooding concentrated on the construction of sea walls that in many places actually withstood the 3-11 tsunami's force, only to be overtopped. As a result of confidence in the sea walls, second lines of defense were limited and emergency power generation capacity was compromised when it was flooded.

Two Historical Examples

Comparison of two older efforts at flood control illustrates Japan's tradition of riparian engineering and some of its limitations and connects them in key ways to the 3-11 disaster. They not only illustrate developments that continue to shape risks and opportunities in Japan, but also help to explain the stimulus to more aggressive civil engineering after World War II. Through both we witness some of the problems embedded in the development of modern Japan. The construction of the Okōtsu Diversion Channel on the Shinano River, Japan's longest stream, was the end product of almost two centuries of efforts. Construction was ultimately only realized utilizing modern engineering technologies in the twentieth century. While construction created a flood tragedy and illustrated limits to the adoption of new technologies, Okōtsu represents the triumph of the modern that lies at the heart of much confidence in technological solutions to flood risk. In contrast, flooding in the town of Tochio, located on a branch stream of the same drainage basin and about ten kilometers south of the Okōtsu project near modern Nagaoka city, presents a different picture. Its flood is more typical of pre-war Japan than Okōtsu. In 1928, at the same time that the Okōtsu project was being modified, Tochio's major flood clearly illustrated limits on the employment of new technologies within Japan. It also highlighted some of the negative impacts of political modernization, a process that removed control over upland watersheds from locals and destroyed long-standing incentive structures to maintain them. In earlier decades such structures had limited flood damage.

Together, these examples illustrate the unevenness of "modernization" of a civil engineering trajectory that ultimately raised new risks such as those that shaped key impacts of 3-11. They also place those developments in a broader, long-term context that suggests not only the constraints on the process of engineering the environment, but also its planners' limited awareness of the potential repercussions of projects and their impacts on public welfare.[10] This characteristic, too, was manifest on 3-11.

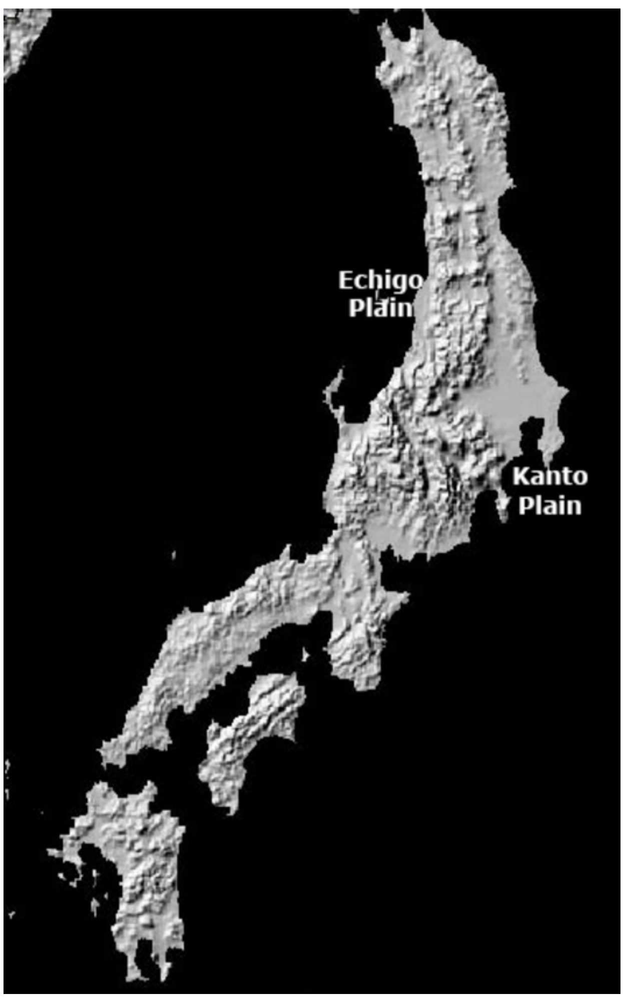


Figure 1. Relief Maps of Japan: Top 1 km Mesh Digital Elevation Model (public domain data); Bottom: extract from National Geographic Society.

The discussion so far has focused on the human side of the run-in between natural forces and human society: it is also important to understand something of the distinctive character of Japan's geography prior to looking at our historical examples. Japan's geography creates tremendous challenges to its population. Equally important, it is very dynamic, especially if we look longer-term, rather than just at individual episodes.[11]

The Landscape

Some background is helpful for readers unfamiliar with Japan but also serves to remind those familiar with it of salient elements of the geographic context in which Japanese civil engineers, historically and today, operate. To begin with, while there are exceptions, North American and European residents typically are accustomed to urban and farmland areas that are relatively stable, with gentle slopes that stretch for a considerable distance; Japan does not enjoy such luxuries. Some 85% of Japan is mountainous and unsuited to dense population and agriculture. Although we call the area around modern Tokyo the Kanto Plain, it is a mistake to think it looks like The Netherlands or Illinois despite common map images. The typical relief maps clearly conceal and "lie" about this fact (Fig. 1). Modern Tokyo Prefecture is very hilly, and clearly mountainous to the West. Even much of downtown Tokyo bears a stronger resemblance to San Francisco than central Ohio, no matter how it looks in Figure 1.

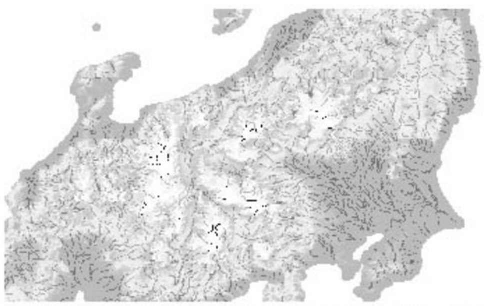


Fig. 2 Relief Map of Central Japan (Philip C. Brown, digital elevation data from National Land Agency, Japan)

Although addition of river drainage detail reveals a greater sense of complex topography, a close-up image (Fig. 2) still conveys a sense of a large flat area around Tokyo, and also in the upper left of the map, the Echigo Plain. As depicted here, coastal plains seem rather wide, but that image, too, is misleading. If viewed from a train traveling along the shoreline they would appear quite narrow in many locations. Even when relatively broad, they are typically less than one to three miles wide.[12]

Contrary to common map images, many Japanese communities are perched precariously on steep hillsides. While there is considerable regional variation, landslides are widespread. From 1950 to 2003, just one of forty-seven prefectures, Niigata, experienced more than 5000 slides, a number of them quite devastating.[13] These same characteristics contribute to frequent localized flooding.

Thus, many areas have characteristics that those of us in North America and Western Europe associate with "marginal" lands. In Japan, given what is available for residence and cultivation and the prominence of irrigated agriculture, people live, work and play in geographic environments that residents in other countries have avoided as marginal. Historically, many areas have not been written off but treated as worthwhile places to exploit with all of the labor, technology and ingenuity that could be mustered.[14]

The Echigo Plain

In contrast to much of the country, the lower reaches of the Shinano River, the Echigo Plain in (modern Niigata Prefecture), are quite broad (although its inland elevations rise sufficiently to host popular ski slopes). It has a very gentle slope. Its large rivers all come from the Japan Alps, from elevations 7,000 feet or more, propelling flows of great force and carrying much silt and debris that clogs downstream river beds.

The Echigo Plain exhibits two other characteristics of Japan and its rivers generally: the steep decent from mountain to plain, and further, the high precipitation common throughout much of Japan. High precipitation is especially prominent along Japan's "backside," the Japan Sea side of the islands. This region takes the full brunt of prevailing Westerlies that absorb moisture as they cross the Sea of Japan and then dump heavy rains and snow on the mountains of central Japan.[15] In combination with the sharp drop in elevation, precipitation patterns create the distinctive characteristics of Japan's rivers: short streams, steep descent, and great variation between peak and low discharge.[16] To illustrate: Fig. 4A compares major Japanese river length and descent with major world streams. It demonstrates that relative to well-known rivers globally, Japan's streams are short and drop quickly from high elevation. Fig. 4B makes similar comparison for peak flood discharge and reveals the impact of heavy seasonal rains on the exceptional flood discharge of her rivers. Other data not graphed here reveals the higher seasonal variation in stream flow relative to major rivers in other parts of the world. Communities all along the narrow river valleys of Japan, not just the plains, thus face considerable risks from floods originating from high precipitation, rapid snow melt, or a combination of the two.

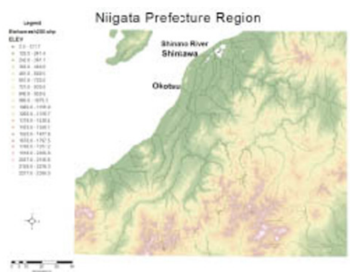
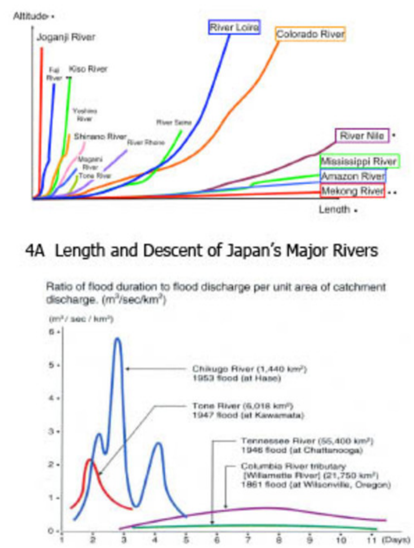


Fig. 3 The Echigo Plain and Highlands of Echigo (Modern Niigata; Philip C. Brown, digital elevation data from National Land Agency, Japan)

The Japanese environment's geographic challenges are reinforced by the nature of rice paddy agriculture. Paddy rice produces more calories per acre than any other plant, but grown in its most productive varieties it requires flat, impervious pans and well-regulated supplies of water, carefully controlled for depth and flow over the course of the growing season.[17] In pre-modern Japan, depositional islands in rivers, especially in lowlands such as the downstream areas of the Shinano, were seen as areas ripe to exploit because of their fertile soils and access to water. While flood risk was substantial, from the late sixteenth century Japanese made constant efforts to exploit these and similar high-risk areas. Because of such efforts the province of Echigo (modern Niigata) became the most populous province in Japan outside of that in which Edo (Tokyo's predecessor) was located. This circumstance arose despite the lack of any dominant city, much less any on the magnitude of Osaka, Kyoto or Edo.

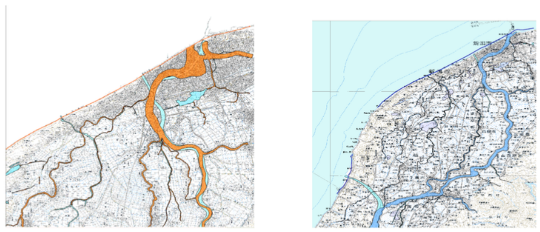


4A Length and Descent of Japan's Major Rivers

4B Intensity of Flood Discharge

Fig. 4 Characteristics of Japan's Rivers in Global Comparison

For the cases discussed below these circumstances resulted in considerable shifts in the course of the Shinano and to the great changes in many smaller bodies of water over the eighteenth and nineteenth centuries. Two maps illustrate. Fig. 5A shows the flow of the Shinano as it entered the Sea of Japan ca. 1600. Note that another river to the north, the Agano, flowed into it, making a broad pool before emptying into the ocean. Note also the width of the river (orange) compared to modern streams (blue). By 1868, Fig. 5B, the situation had changed completely. The Agano now independently flowed into the Sea of Japan, and while still broader than its modern counterpart, the Shinano's stream more closely approximated its modern bed. Although difficult to discern on this map, note the light blue ponds and lakes that the cartographer has added to the modern map (roughly the center) to show the locations and extent of water bodies that have been drained since 1868 (most since the end of World War II). All suggest the susceptibility of this area to flooding, despite its high agricultural output, and the degree to which it has been re-engineered over the past century.



A. Lower Shinano ca. 1600

B. Lower Shinano ca. 1870

Figure 5 Comparison of Lower Shinano River Flow

Map: Philip Brown, based on data from the data disk included with Kokudo Kōtsūshō Hokuriku Chihō Seibikyoku, Kokudo Kōtsūshō Kokudo Chiriin. *Kochiri Ni Kansuru Chōsa: Kochiri De Saguru Echigo No Hensen - Arakawa, Aganogawa, Shinanogawa, Himekawa* [in Japanese]. Niigata: Kokudo Kōtsūshō Hokuriku Chihō Seibikyoku, 2004.

As regards the issues under consideration here, the lower Shinano was generally typical of Japan: human settlement in a geologically unstable area was unavoidable, although human choices might ameliorate the disastrous impact of natural forces. The people of Niigata, indeed, the people of Japan, were quite willing to do all they could to control natural forces through civil engineering. As noted above, popular images to the contrary, the Okōtsu case discussed below can be multiplied many times to provide strong evidence that Japanese have long employed engineering in an effort to control their environment.[18]

This said, the people of Echigo and many other Japanese also pursued *non-engineering* options when dealing with the risk of floods. In particular, its rural communities practiced various forms of "zoning," broadly conceived. In part this came through names attached to dangerous places, e.g., Ochimizu or "falling water," Ochida, "falling paddy," and the like.[19] In other instances, the effects of flood and other natural hazard risk were ameliorated through the use of joint ownership of arable land, under which share-holding cultivators received rights to cultivate the same proportionally structured, risk adjusted portfolio of fields.[20]

Within this geographic context, one of the examples below deals with civil engineering, the other with disruption of a non-engineering approach to flood amelioration and the unintended consequences of both approaches.

The Okōtsu Diversion Channel[21]

In brief, plans for a diversion channel south of Niigata town (now city) on Japan's northwestern coast were first floated in the early eighteenth century by a combination of local merchants upstream from Niigata Town, wealthy landowners and others anxious to reduce the threats of flooding to their own economic activities. Some supporters also hoped to profit directly from construction contracts. The Okōtsu diversion was one of a number of similar projects in the region. However, unlike projects on the Agano River and the Nishi River that were funded, the Okōtsu project was just too big to garner financial support prior to 1868 when the Meiji Restoration brought Japan its first, modern, centralized national government. Not only was construction cost a concern, farmers and merchants downstream argued against the project. Merchants on the river claimed that even this type of overflow weir would, in fact, lower the river's already shallow water level and reduce the scouring effects of the river as it passed through Niigata harbor. Shallower waters would impede transport in both the harbor and on the river. Opponents also pointed to the potential disaster if the dam collapsed, as had the Agano diversion facility in 1731. Constructed or not, the Okōtsu plans and many other smaller projects demonstrate pre-modern Japan's eagerness to re-shape its riparian environment, a policy foundation for later water control developments and the later adoption of improved, modern technologies.

Shortly after bringing anti-Bakufu campaigns to a conclusion (1869), the new central government, anxious to garner domestic and foreign support, and to project an image of modernity, announced its direct control over major rivers, and commenced large projects. Among the projects funded was the Okōtsu diversion channel. Begun in 1869, it was designed to ameliorate flooding by providing for efficient transport of surplus water from the lowlands to the Sea of Japan. Construction proceeded quickly. By 1875, 90% of the 10-kilometer channel was dug; only the diversion weir remained to be constructed. Nonetheless, downstream farmers' and merchants' vociferous opposition to the project, long a hallmark of local debates over the project since it was first proposed, persisted. Ultimately the central government responded by sending two European advisers to investigate. Their concerns paralleled a number of those expressed by channel's downstream opponents. In the end, publicly based on their recommendations, but likely reflecting growing fiscal challenges to the central government budget, completion of the project was cancelled (1875).[22]

Upon cancellation of construction, the national administration encouraged local forces to focus on building traditional dikes. They were to rely on their own resources, although modest central government expenditures later supplemented local efforts. Construction of small dikes limped along over the next three decades, proving largely ineffective in constraining such a large stream.

Cancellation of the channel appealed to many who lived downstream from the proposed diversion weir. Most influential among them were the urban residents of Niigata town and their rural merchant allies. Some feared the large-scale disaster that would occur if the weir collapsed, as had happened elsewhere. Such a collapse would harm river-borne transport by lowering water depth and limiting boat size. Others, including Europeans desirous of using Niigata as an international harbor, fretted that even a viable weir would slow the flow of the Shinano and exacerbate soil deposition. Further, a slower stream would reduce natural scouring of Niigata's already-shallow harbor (a seven foot draft) which already struggled to handle Western commercial vessels. (Such fractiousness was echoed in the divisions of power and economic role that characterized proponents and opponents of nuclear power plants a century later.)

The success of channel opponents notwithstanding, the same coalition of local supporters who had proposed and advocated for the initial project continued to agitate for construction of a major diversion channel. They also attempted to garner support for smaller projects such as traditional dikes. Yet the dream of a channel that would be more effective (they argued) in reducing flood damage never died. This group remained an important force for completion of a modern diversion channel well into the twentieth century.

A combination of disastrous flooding nationwide, especially in Niigata, in 1896, and funds from the indemnity China incurred as a result of its defeat in the Sino-Japanese War ultimately tipped the policy balance. The central government once again determined to invest in major flood control efforts, including Okōtsu. Under these circumstances, local opposition could not prevail that supported both domestic and international transport.

Once begun, construction took more than a decade (1909-1922). Difficulties plagued the project. Excavations triggered landslides that silted up Teradomari harbor. Corrective measures undid the damage, but at a considerable cost overrun. Such incidents encouraged energized criticism of the project by its long-standing opponents, but this time the central government was not to be deterred.

No one foresaw the real calamity, the 1927 collapse of the diversion weir. Engineers' estimation of the potentially damaging effects of sub-surface hydraulic action lay at the heart of the failure. Beneath the surface of the river, the water's hydraulic action flushed away the soil around the foundations of the movable weir that controlled overflow, and, over five years, weakened foundations to the point of complete collapse, a milder parallel to the underestimation of natural forces that was a source of major problems at Fukushima. It completely stopped the downstream flow of the Shinano and re-channeled all of its waters down the diversion channel. Farmland was destroyed, transportation ceased, drinking water was rendered unpotable, salinization (as the ocean waters surged into the Shinano's river bed) damaged downstream lands, and the lack of river flow created a cesspool of flood debris, industrial, animal and human waste.[23]

To opponents, this tragedy proved the folly of the entire project, yet in concert with local supporters the central government pushed on with re-design and repairs, convinced of its long-term efficacy in flood amelioration, an argument bolstered by the first years' generally positive experience with the diversion project. Repairs were completed and the channel reopened in 1931. The channel has remained in use ever since. And no one can argue that it has not delivered benefits in the form of reduced flooding on the Shinano River itself.

Clear benefits notwithstanding, questions remain about the unforeseen consequences of this and related downstream engineering, especially the construction of diversion channels. Like New Orleans in the U.S., the downstream Shinano and city of Niigata are sites of some of the most significant subsidence in Japan, in part a result of reduced soil deposition, but also a consequence of population growth with its consequent increased demands for sub-surface water. Further, population increase constitutes one of the paradoxical outcomes of flood-control – people's faith in dikes and other projects' ability to create a safe environment leads them to exploit lands still unsafe, as shown, by the Niigata inundations of July, 2004, 40 years after a major tsunami.[24] While increasingly accurate weather forecasting and speedy communications reduce the loss of life, and while the area subject to flooding has decreased, the constant financial value of losses has increased over time, both locally and nationally. If a tsunami struck downtown Niigata now, as it did in 1964, more people, more property and a larger area would be subject to lingering floods than was true in the past because subsidence has dropped more land below sea level. Here we see unintended risks due to what, from the perspective of flood prevention on the Shinano, many residents count as a success.[25]

The Great Tochio Flood[26]

While Okōtsu's history represents one set of paradoxes of technological modernization, The Great Tochio Flood of 1928 exemplifies both the selective implementation of such approaches and the limits to Japan's technological and politico-economic modernization in the form of tax modernization. The end result was ecologically different than that seen in the downstream reaches of the Shinano, but it similarly manifested consequences that the urban, former samurai bureaucrats who planned and administered it did not anticipate.

Situated just upstream from Okōtsu on tributaries of the Shinano, the town of Tochio never benefitted from modern flood amelioration technologies. It continued to use largely the same approaches and technologies that would have been used 300 years earlier. During this flood, old-fashioned dikes were breached in 170 places; raging waters destroyed them completely at 42 sites. Flooding washed away roads, rail lines and bridges. Of more than 1500 houses prior to the flood, fifty-nine were washed away entirely, twenty-seven houses not swept away were rendered completely unusable, 239 were counted as half lost, twelve were buried in mud, and water came up above the raised floors of 917 homes.

Not only were these losses caused by a failure to implement more modern technologies and strategies of flood amelioration, an act of conscious political choice within the central government, but they were also the result of unforeseen consequences of the implementation of a modern land tax structure. Based on the British model and successfully financing the new Meiji central government, the new policy divided lands into privately held and explicitly public lands (the Meiji Land Tax Reform, 1873-1877). Communities that had previously managed commons (*iriaichi*), including many woodlands located in upland districts, were frequently denied managerial control of access to their benefits once they became public lands.[27]

The new tax structure thus destroyed traditional mechanisms of maintaining watersheds – sophisticated local institutions to manage who could enter them and harvest resources, to determine how much grass, small timbers and other resources could be removed. These same institutions investigated violations and administered punishments for violators. As in much of Japan, such lands provided locally managed resources to nearby villagers for centuries. Villagers of one community, or several hamlets together, practiced joint management that sustained resources and maintained uplands as flood-reducing watershed. Once relieved of such control, the watershed near Tochio began to suffer.

Accordingly, the 1928 flood was not a one-off event. It marked a crescendo of increasing floods over the decades since the implementation of the new tax structure. Townsmen attributed the increasing incidence of flooding to the denuding of a local mountain, Sumon. With the land tax reform, these uplands were taken over by the state, the mechanisms of local control eliminated, and no substitute provided. Consequently, its forest resources were wantonly pilfered by unchecked free riders.

Had central authorities recognized the value of traditional practices and made some provision for a functional substitute, some flood damage might have been avoided. As with tsunami markers in Tohoku, local folk knowledge was ignored. Had the new national land tax system not denied local governments the ability to raise funds sufficient to finance stronger dikes or to dredge with modern equipment, the erosion caused by denuding of the watershed might have been offset. That, too, was not to be. Just as residents in the Tohoku area ignored stone markers set to remind people of the historical highs of tsunami waters and built residences, shops and factories at lower levels, the leaders of the Meijji government swept aside long historical practice in their effort to create taxable revenues to finance a newly centralized state that aspired to equalilty with "civilized" Western states.[28]

To replace local measures of flood amelioration, the central government did nothing. The prefecture lacked independent funds to do anything. Local resources were inadequate to do anything beyond maintain traditional dikes and use traditional techniques of silt removal.

The pressures of World War II later exacerbated failures of this sort. As supplies of fuel dwindled, hills were broadly overcut – a true free rider phenomenon. This in turn aggravated floods, especially in the years immediately following the war's end as typhoon after typhoon hit Japan, with the largest, Kathleen (1947) breaking historic records.[29]

Reflecting on Japan's post World War II riparian construction boom, we can understand that the cumulative impacts of events like the Tochio flood were one major stimulus, encouraged by occupation forces as they witnessed post-war floods, to aggressive re-engineering of Japan's rivers to limit flood damage.[30]

Final Observations

The pre-war pattern of state control central to the stories of both Okōtsu and Tochio set important patterns for post-war management of riparian projects. The numbers of new dikes, dams and spillways exploded, first as part of post-war recovery efforts, then pushed to further enhance economic growth, and finally employed as a counter-weight to a slowing and ultimately stagnant economy. These examples can be multiplied many times in both pre- and post-war eras. Financial control was and remains in the hands of the central government. National bureaucracies control much planning, and while local input, as with Okōtsu, is actively sought, local knowledge may well be ignored. Thus, for example, permits for suburban housing developments (e.g., those south of Niigata city which were flooded in 2004) are granted for locations that in practice have remained subject to flood hazards, despite expectations to the contrary. Risks frequently are masked by changing place names to be more attractive or pointing to modern dikes as secure protectors -- to the ultimate detriment of new residents unfamiliar with local conditions or (overly) confident in the ability of modern technologies to protect their property.

The result of much planning: unanticipated calamities, at least from the perspective of victims, but frequently from that of planners as well. Among them, the impact of the built environment stands out. New construction changed the dynamics of water coursing through rivers to create new weaknesses in dikes. It channeled and contained tsunami waters on 3-11. It has evoked human responses that aggravated exposure to flood and tsunami risk.

The nature of internal bureaucratic discussions of risk is not easy to explore and therefore it is difficult to know how administrators define, discuss and evaluate risk en route to publication of their conclusions. The content of deliberations on risk remains largely undisclosed, with just the final, official reports opened to the public. Individuals who break ranks to provide insights or to express their concerns publicly are very rare in the Japanese context.

Nonetheless, in widespread popular understanding and official judgments we can read the high degree of confidence invested in the built environments of flood control (as well as the breakwaters of the Tohoku coastal region, or the safety devices of the Fukushima nuclear power plants). At the very least we can read acquiescence to heavy reliance on "hard" civil engineering solutions.[31] Most efforts to control nature historically were not newly motivated by a need to protect nuclear facilities. The stimulus for massive riparian engineering projects can be traced to the seventeenth century and earlier and they were grounded in completely different objectives: water supply and general flood amelioration. Nonetheless, technological developments inaugurated to accomplish these goals, and their success in addressing one set of problems (e.g., flooding) built confidence in engineers' abilities to address natural risks and thereby to protect nuclear facilities, too.[32] In this regard, planning nuclear sites to withstand earthquakes and tsunamis as well as other natural forces has much in common with activities designed to control floods and landslides – building dikes, multi-purpose dams, or lining Japan's verdant hillsides with cement screens and anchors.

Widespread use of civil engineering to address problems in the intersection of the natural environment and human society has engendered newsworthy popular opposition to riparian control and other projects. Popular efforts to de-commission some existing riparian facilities such as the No. 10 dam on the Yoshino River (Tokushima) or Kumamoto's Arase dam, to name just two examples, speak to their impact.[33] Local movements in support of such efforts came together in a national conference of ecologically minded critics, the National Symposium on Rivers (*Kawa no zenkoku shinpo*) held in Tokushima in August 2007, and its meetings continue annually.[34] The Democratic Party of Japan incorporated and highlighted proposals of popular groups to limit and reverse civil engineering projects in its "Manifesto," thus demonstrating their broad appeal. The election of environmentalist Kada Yukiko (then a member of the Democratic Party of Japan) as governor of Shiga Prefecture and other electoral successes further demonstrated broad support for environmentalist critics. In 2009, these efforts culminated in a Diet majority for the Democratic Party, and its post-election pronouncements froze hundreds of dam construction projects that signaled environmentalist victory. Those successes turned out to be more apparent than real, implementation interrupted by internal squabbling and the bungling actions of successive Democratic cabinets. Ultimately, the Democratic Party lost control of the Diet to a revived Liberal Democratic Party in late 2012.

Despite scattered successes of critics in stopping construction plans or decommissioning dams, long-term historical reliance on "hard" solutions has been difficult to reverse. Most projects on the books in 2009 have continued under construction; now they comprise a core element of Prime Minister Shinzō Abe's effort to revive the Japanese economy by extensive central government initiated investment in public works.[35] Broadly speaking, the pattern of central dominance dates to the Meiji Restoration (1868), when the new government quickly removed early modern options for local control and replaced them with structures bureaucratically and financially subservient to the national administration. After an initial burst of energy (e.g., the first Okōtsu construction), government initiative retreated for financial reasons, but still left local administration with puny financial resources to act in place of central funding.

Thus local control of river engineering, especially over large projects, was never a serious option on rivers in modern times. With funding dominated by national sources and national bureaucracies, planners and legislators frequently give substantial emphasis on the needs of non-resident stakeholders, not just those of locals. In this context, economic policy, provision of water and electric power for industry in the Kanto and other metropolitan centers, or generating an economic stimulus that would at least momentarily benefit the national GDP and briefly goose struggling rural economies all appear to play as prominent a role in planning as do high levels of confidence in technological solutions.

In ordinary times, riparian engineering projects and modernization programs can be seen as providing tangible benefits, but the overall cost-benefit calculation may be a wash when one considers the long-term unanticipated consequences (lower Echigo's subsidence, increased flooding in Tochio, water retention at Fukushima) are factored in. In these circumstances the damage skyrockets and negative effects mount for the populations that riparian and other projects were designed to protect.[36] Trends such as this suggest just how difficult it is to live in "harmony" with nature using massive applications of technology.

Clearly some potential dangers have been altogether left out of planning equations because they were unimagined (e.g., subsidence in the Niigata area), minimized because of their infrequency in recent times (typically, the times over which official disaster statistics have been regularly kept, about a century), or otherwise ignored or covered up even where they were imagined (as in areas of downstream residential housing development). As applied to ramifications of natural forces, the concept of "risk" is employed only where there is a possibility of damaging human activities and existence (even in arguably anthropogenic events). We care about "hazards" only as they affect human society. Yet the cases noted above, as well as 3-11 (both broadly defined as earthquake-tsunami and more narrowly treated as nuclear threat), suggest that both "risk" and "hazard" require broader definition, one that recognizes the role of human choice in creating risk and one that imagines a greater range of threats and potential costs to proposed solutions, even if those options reduce disruptions with the use of civil engineering.

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Notes

[1] In addition to the impact of narrowing cement tubes, on tsunami waters, one can discern similar effects as water courses between buildings that line narrow streets and even narrowing valleys generally. See for example: "2011 Japan Tsunami the View from the Town Office of Yamada." And "2011 Japan Tsunami: Ascending the River in Kesennuma [Extended]".

[2] An interesting illustration of both sources of "narrow vision" appears in a recent radio broadcast, Joyce (2013). It can be argued that engineering is an historical discipline, based in part on continuing experience of trial, failure and adjustment. The key issue facing planners and engineers is that of anticipating the unimaginable. On this interpretation of the role of failure in engineering progress, see Petroski (1985).

[3] One benchmark statement focused on different contexts of complex systems is Perrow (1999/1984), that was inspired by the nuclear accident of Three Mile Island. A more popular account, which treats Chernobyl among other incidents, is Chiles (2001). On small-scale examples, see Tenner (1996).

[4] Among a number of examples focused on cases of a different sort than those taken up here, see, for example George (2001), Walker (2010), Miller, Thomas and Walker (2013).

[5] Perhaps the most widely read discussion of the difference in stream flow along its sides as opposed to stream center may be that found in the discussion of chaos theory in Gleick (1987).

[6] In the U.S., the Los Angeles River provides one of the most widely known examples of this phenomenon.

[7] The damage associated with these floods is detailed in several works, e.g., the photo essay by Nipōsha (2004) and the specialized research reports of Takahama (2005).

[8] In the Mississippi and other environments this

phenomenon is referred to as a "sand boil." See the well-known study of Barry (1997).

[9] See Atwater (2005).

[10] The link between projects designed to address an environmental issue and unintended negative consequences on the environment I discuss here has been treated in other contexts. See, e.g., (Radkau, Radkau and German Historical Institute in London.). However, the impacts I note here have not been well explored in the Japanese context to my knowledge.

[11] I have in mind here not only earthquakes, but also volcanic activity.

[12] Maps are drawn this way because the human eye can only readily distinguish just five or so shades of gray or different colors, and using them to depict an island (Honshu) that at its greatest extent is only some 255 miles wide, but which has elevation from below sea level to over 10,000 feet demands coarse classification of elevation.

[13] Nihon Jisuberi Gakkai (2008: 17).

[14] A corollary of sorts: although nuclear plants typically have been sited in very narrow coastal plains wedged between sea and mountain, *most* coastal areas are similarly very limited in breadth and at best only relatively broader. If there is not really much choice in siting nuclear power plants in most of Japan, this constraint exposes them to possible tsunami.

[15] The annual precipitation map of Japan reflects the influence of the Japan Sea. See for example http://omsolar.jp/image/weather/section02_img07.jpg.

[16] The Ministry of Land, Infrastructure, Transport and Tourism has posted a useful statistical table that describes key features of Japan's major rivers.: http://www.mlit.go.jp/river/basic_info/english/table.html.

[17] It is a mistake to think that: 1) paddy rice is the only variety of rice, or 2) that ordinary Japanese have traditionally eaten rice. There are upland, dry field varieties of rice, and others that simply grow in perpetually watered areas (like the shores of rivers in that drain into Charleston, South Carolina). However, these are less productive than well-regulated paddy rice. Until the late nineteenth and early twentieth centuries, when circumstances began to change, rice, especially that of good quality, was for the relatively wealthy and special occasions only.

[18] Just as Japan has proven willing to force natural circumstances to bend to its will, the idea of "nature" itself has been subject to manipulation. See e.g. Thomas (2001).

[19] For a collection of examples for Niigata Prefecture only, see Igarashi (1995).

[20] Historians of technology sometimes classify this kind of approach as "soft," in contrast to "hard" measures like civil engineering projects, efforts to manipulate the environment physically. For more on this topic, see Brown (2011a).

[21] The original form of the weir for this project (eighteenth century) resembled a low dike that would overflow on one side of the stream; on the other side was a higher embankment. In some instances, engineers did not use this technique to divert water into a drainage channel, but instead to divert water into an overflow zone. Lands in this zone were limited in the use to which they could be put. This arrangement is sometimes dubbed "Shingen *tsutumi*" (literally, "Shingen dike") after daimyo Takeda Shingen with whom legend links this style of flood amelioration to the famous daimyo Takeda Shingen and his efforts to limit the losses from floods in his domains. (This case is discussed in more detail in Brown,

2013).

[22] As the new Japanese government began its operation, double entry and other accounting practices such as those employed in Europe at the time had not yet made their way into administrative practice. It would take about a decade to establish a modern budgetary regime. Brown (2010).

[23] Materials (wood, not steel) may also have played a role, but the role of erosion caused by hydraulic action is indisputable. In the repairs that followed, provision was made to reduce the flow of water at potentially vulnerable points to reduce the force of hydraulic action.

[24] The scale and human costs of these two events was quite different. The Niigata earthquake and associated tsunami wreaked havoc on much of the west coast of northern Japan and Sado Island. Because both caused damage to a major urban area, more than three dozen people lost their lives, six or seven times more than in 2004. Economic damage to downtown transportation infrastructure and industry was significant in 1964, but confined largely to suburban areas in 2004.

[25] During research in Niigata in 2008 I had a number of conversations with people who sought to assemble a formal proposal to have the entire lower Echigo Plain designated as a UNESCO heritage site on the grounds that the Okōtsu and related projects had made the modern development of the region possible.

[26] I have developed this case more fully in an unpublished presentation, Brown (2011c).

[27] Margaret McKean has been the leading Western scholar of the Japanese commons to date. See McKean and Cox (1982).

[28] Japanese slogans of the time spoke of "civilization and enlightenment," *bunmei kaika* 文明開化.

[29] A preliminary assessment of ecological issues associated with wartime Japan can be found in Tsutsui (2003).

[30] In Kraebel (1950).

[31] My conclusion about public attitude is based in part on the limited public questioning of construction and its ecological impacts, and the government's continued push to move ahead with the hundreds of dikes and dams currently under construction or planned even as these focus on situations in which "bang for the buck" is reduced because the most beneficial targets have already been exploited. There is a strong argument to be made that increased public cooperation is bought. See, e.g., Dusinberre (2012).

[32] I think it is fair to say that nuclear power plants themselves are efforts to "control nature" in the same sense that manipulating any reaction in chemistry or physics would be, but the idea of controlling large-scale natural forces such as floods and tsunami that are either not anthropogenic or only partially anthropogenic constitutes a different enterprise.

[33] On the No. 10 dam, see Himeno (2011) and numerous web sites. On Arase's decommissioning, see "Kyōdai Damu O Tekkyo Shiyo: Roku Nen Gakaride Susumu Nihon Hajime No Kōji," *Nihon keizai shinbun (denshi-ban)* August 8, (2013).

[34] Reports from these meetings, video clips of presentations, etc. can readily be found posted on Japanese language web sites.

[35] One example of a contentious, continuing project is that of Yamba dam see Brown (2011b, 2013).

[36] Perrow (1999) argues that this tendency is present in many realms in which the scale at which technology is applied increases.