

GEOPOLITICS & PRUSSIAN TECHNICAL EDUCATION IN THE LATE-EIGHTEENTH CENTURY¹

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Geopolitics & Prussian technical education in the late-eighteenth century

Summary: *Technical instruction in eighteenth-century Prussia—both military and civilian—flattered for most of the century. In the military, promising technical achievements, such Leonhard Euler's application of the calculus to Benjamin Robins' ballistics, were accompanied by weak institutional settings for training military engineers,*

1. An abbreviated version of this essay was presented as the plenary lecture at the X Trobada d'Història de la Ciència i de la Tècnica in Lleida, Spain on Nov. 13, 2008. I thank Antoni Roca-Rosell and his colleagues for their gracious invitation and conference participants for their perceptive remarks. This essay is drawn from my book-in-progress, *Prussian Precision, 1648-1947*, Chapter 3, «Public Works and Exactitude». Parts of this project were supported by the National Science Foundation, the National Endowment for the Humanities, the Georgetown University Graduate School, and last, but not least, the BMW Center for German & European Studies at Georgetown. I thank them one and all.

The following abbreviations are used below: Geheimes Staatsarchiv Preußischer Kulturbesitz (GStA PK), Generaldirektorium (GD), Hauptabteilung (HA), Niedersächsische Staats- und Universitätsbibliothek (NSUB), *Sammlung nützlicher Aufsätze und Nachrichten* (SNA).

with the result that much of the best military technical training continued to take place by apprenticeship. Civilian technical instruction fared better thanks to the expansion of Prussia. Obtaining control over Prussia's territorial acquisitions in many respects demanded greater technical expertise than the wars that yielded them. This essay argues for the importance of Prussian territorial expansion from 1742, when Prussia acquired Silesia, to the three Polish partitions in 1772, 1793, and 1795, in shaping Prussian technical instruction in civil engineering. Specifically, the geography of the North European Plain—with its marshes and bogs, lakes and lagoons, and numerous waterways—presented formidable challenges, especially in hydraulic engineering. Field experiences in that region were decisive in shaping Prussian civil engineering practices that, at the end of the century, became the foundation of technical instruction at the Bauakademie, Prussia's technical school for civil engineering and architecture, established in 1799. The Bauakademie was the earliest predecessor of the Technische Hochschule in Berlin (1879).

Key words: Technical instruction, Prussia, eighteenth-century hydraulic engineering, Bauakademie

Introduction

For most of the eighteenth century, Prussia was a geographical jigsaw puzzle. Its key province, Brandenburg, was on the west surrounded at a distance by a territorial archipelago dotting the Holy Roman Empire, and on the east separated from the country's eastern-most province, East Prussia (Ducal Prussia), by the vast plains of the Polish-Lithuanian Commonwealth. Wars expanded Prussian territory considerably, helping to create geographical continuity. In the Wars of Austrian Succession, Frederick the Great acquired Silesia in 1741, and with it most of the Oder River. Decades later the war between the Polish-Lithuanian Commonwealth and Russia resulted in the division of Poland among the victors. As a result of three Polish partitions, Prussia nearly doubled its size, gaining the provinces of West Prussia and the Netzedistrikt in 1772, South Prussia in 1793, and finally New East Prussia in 1795. Altogether Prussia's expansion over nearly fifty years amounted to roughly 340,000 square kilometers. All of these new provinces shared a similar geography: flat, marshy land laced with rivers—a nightmare to traverse in any season but winter when the ground water was frozen. Populated by Poles and Slavs, Prussians considered these provinces «wilderness» in need of taming. Prussians civilized that wilderness through hydraulic engineering projects that drained land for colonization and linked waterways for transport. Massive in scale, these ventures helped to define the Prussian state, molded Prussian engineering instruction, and

shaped the attitude and outlook of the Prussian engineer as well as his relationship to the state.

None of these hydraulic engineering projects were easy to execute. The draining and rerouting of the Oder River in Silesia between 1747 and 1753 illustrate their challenges and complexities. Life on either side of the Oder had been conditioned for centuries by twice-yearly flooding, after the snow melt in the spring, and then again in the summer. The nature of the Oder in several areas was not that of a river flowing from its source to mouth, but rather of a body of water that saturated land and meandered through the landscape carving out sandbars and little islands whose locations and configurations changed with every flood. Wartime experiences on the Oderbruch, the marshy area bordering the river, convinced Frederick II (r. 1740-1786) to drain the area to facilitate troop maneuverability, to

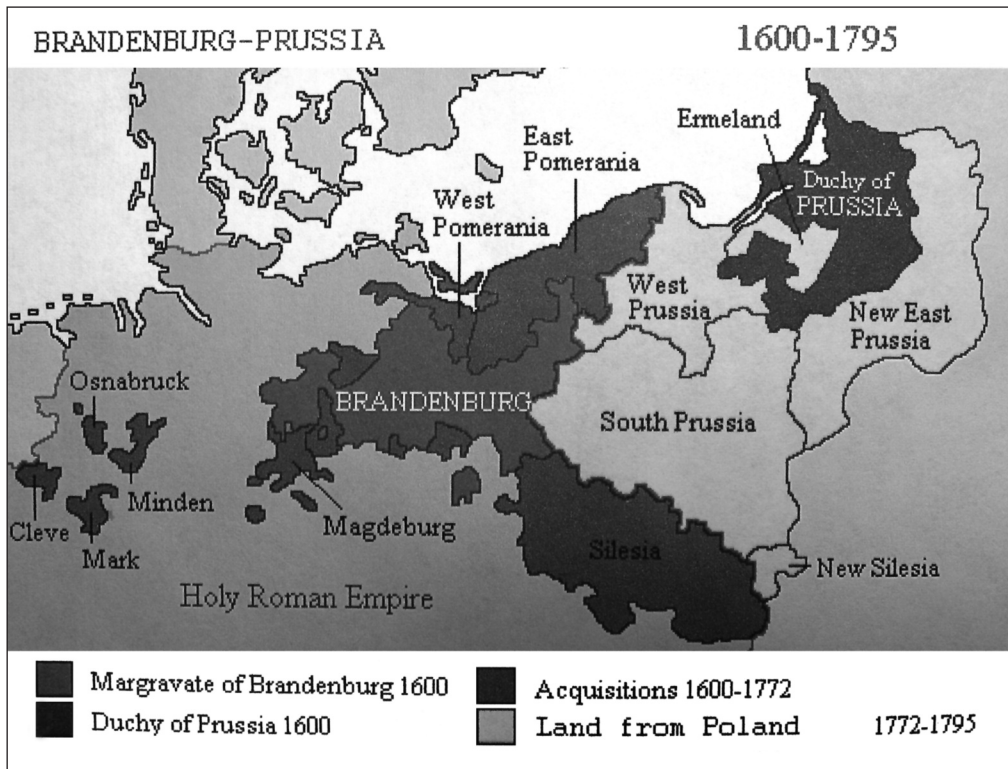


Figure 1. Prussian Territorial Expansion, 1600-1795.

Source: <http://commons.wikimedia.org/wiki/File:Acprussiama2.gif>

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improve water transport, as well as to create new sites for settlement and farming. His subsequent management of newly acquired land created a template for development that he and his successors deployed repeatedly over the century. The rerouting of the Oder River and the draining of the marshland on either side of the river covered an area about sixty kilometers long and twelve to twenty kilometers wide. The plan to reroute the Oder and reclaim land was conceived as a part of economic and demographic modernization that included increasing trade, having greater access to major water routes, exchanging indigenous fishing for farming, and creating a more profitable region economically. The attempt to control nature, though, was anything but. Flooding persisted, as it still does today. With each flood the force of the water moved the Oder closer to its older meandering configuration, and each time the dikes, dams and locks were repaired to bring the Oder back to its straighter route.²

Predicting and controlling the flow of water properly required careful measurements of elevation and the horizon. In addition, for the construction of locks that would enable travel over a gradient, the water's volume and velocity had to be computed accurately. Neither set of measurements was easy. Records for the project indicate that those who worked on it wanted to «measure and level accurately», but constantly fell short of their goal. Surveying the Oderbruch was always a complex balancing act: soggy land made it difficult to determine the horizon; hundreds of people had to be organized and coordinated (at the height of the project approximately 1,000 people worked in a single day); bad weather threw schedules off; sickness, including malaria, always threatened; and the labor force either worked against the clock to keep costs down (the budgets were always inaccurate) or sabotaged the project, obstructing its progress. Military engineers—called to the project belatedly and always few in number—were not always prepared for the technical difficulties involved: they had to be instructed on the spot in how to perform leveling on a marshy terrain that compromised accurate readings. The river's gradient proved to be the project's Achilles heel, especially at the Finow Canal, which linked the Oder and Havel Rivers.³ Both on the Oder River and at the Finow Canal, the number of locks had to be continual-

2. On the Oderbruch region, and the project of 1747-53 in particular, see: Gerd Heinrich, «Friedrich der Grosse und die Preussische Wasserstrassenpolitik», in Helmut Neuhaus, ed., *Verfassung und Verwaltung* (Köln: Böhlau Verlag, 1994), 103-123; Bernd Hermann, «Nun blüht es von End' zu End' all überall». *Die Eindeichung des Nieder-Oderbruches, 1747-1753: Umweltgeschichtliche Materialien zum Wandel eines Naturraums*. Cottbuser Studien zur Geschichte von Technik, Arbeit, und Umwelt, Bd. 4 (Münster: Waxmann, 1997); Siegfried Bacher, *Kulturhistorische Landschaftselemente in Brandenburg: Entwässerungssysteme am Beispiel des Oderbruchs* (Berlin: Verlag für Wissenschaft und Forschung, 1999); David Blackbourn, *The Conquest of Nature: Water, Landscape, and the Making of Modern Germany* (New York: W. W. Norton, 2006), 21-76.

3. GStA PK, II. HA GD, Abt. Kurmark, Tit. CCLXXIX, Lit. F, Nr. 2, Bd. 8, fols. 1, 3-6; David Gilly, «Kurzgefasste Darstellung der vorzüglichsten Gegenstände der Land- und Wasser-Baukunst in Pommern, Preußen, und einem Theil der Neu- und Kurmark», *SNA* 1.1 (1797): 26-52, on 39-43.

ly adjusted to fit the gradient properly—an indication that the leveling had not been done accurately.⁴

That the project was completed at all is remarkable given that at the time, there was in Prussia no rigorously formal means for training civil engineers. The project's director, the engineer Simon Leonhard van Haerlem, came from a family of hydraulic engineers based in Hanover. The mathematician Leonhard Euler (1707-1783), whom Frederick II had brought to the Berlin Academy of Sciences along with other mathematicians to assist in state economic projects, figured out how to reduce the labor required for the project by demonstrating that the sheer force of the water flowing through the new route would complete the dredging to the necessary depth. At crucial points Euler and his team—which included his teenage son Johann Albrecht Euler (1734-1800)—took the leveling measurements necessary to determine such matters as the size of dikes and the location of locks. Although there can be no doubt that in Prussia the skills to handle such a complicated task had improved to some degree since the beginning of the century—especially in the handling of the level—Prussian technicians simply did not possess the expertise or wherewithal of their French, Dutch, or English contemporaries. Prussian technicians had in fact been late in adopting a principal instrument in hydraulic engineering, the level. The first Prussian book on the level, from 1715, castigated Prussian technicians for their ignorance of the instrument and their unwillingness to recognize the economic advantages that could be accrued from accurate leveling.⁵ In an effort to improve Prussian practices, Frederick II subsidized the publication of two books on the level while the Oderbruch project was ongoing: in 1749, a German translation of the most advanced treatment of the level, by Jean Picard, originally published in French by Philippe de la Hire; and in 1750, a textbook by his former teacher, the fortification engineer Abraham von Humbert.⁶ By then Dutch, French, and English engineers and surveyors were using telescopes to increase the accuracy of readings with a level, but Prussians were still learning the basics.

Difficulties in executing the Oderbruch project were in part due to the state of Prussia's technical training. Until well after the Oderbruch project, Prussian technical instruction was weak in both the military and civilian sectors. In 1717 Prussia's «Soldier King», Frederick William I, formalized military instruction in cadet academies for lesser nobles who could not afford an education for their sons, and in 1729 he organized the army's engineer-

4. GStA PK, II. HA GD, Abt. Kurmark, Tit. 272 Wassersachen Oder, Nr. 3, Bd. 1.

5. Leonhard Christoph Sturm, *Aufrichtige Entdeckung des zu Aufnahme der Länder und Commerciens höchst-nützlichen Nivellirens oder Wasserwägens* (Augsburg: Peter Detleffsen, 1715), [1], [4].

6. Jean Picard, *Abhandlung vom Wasserwägen, nebst einer Nachricht von etlichen Wasserwägungen*, ed. Philippe de la Hire, trans. Daniel Passavant (Berlin: n.p., 1749), originally published as Jean Picard, *Traité du Nivellement*, ed. Philippe de la Hire (Paris: Michallet, 1684); Abraham von Humbert, *Neue Anweisung zum practischen Gebrauch des Nivellirens mit der ordentlichen Wasser-Wage worinnen zugleich eine richtige Anleitung gegeben wird wie man sich dieses Instruments recht bedienen soll* (Berlin: A. Haude und J. C. Spener, 1750).

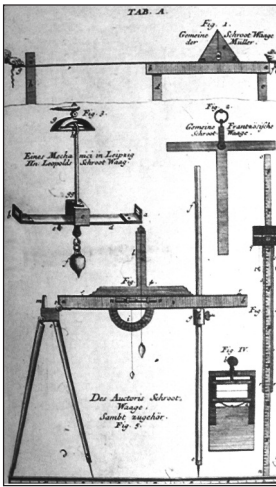


Figure 2. Early-18th-century levels.

Source: Leonhard Christoph Sturm, *Aufrichtige Entdeckung des zu Aufnahme der Länder und Commerciens höchst-nützlichen Nivellirens oder Wasserwägens* (Augsburg: Peter Detleffsen, 1715), Table A. Photo courtesy NSUB.

ing corps. But the number of Prussian military engineers remained stagnant at around forty for the first half of the century; most were involved in fortification or military surveying.⁷ An early civilian technical institute was the *Akademie der Mahler, Bildhauer und Architektur*—renamed the *Königliche Preußische Akademie der Künste und mechanischen Wissenschaften* in 1704—but instruction in it focused primarily on the aesthetic side of art and architecture with the result that the «mechanical sciences» were initially viewed in anatomical terms, as having to do with the construction and motion of the human body. A weak institution a decade after it opened, the *Akademie der Künste* in any event did not stress or develop technical instruction, even though some historians trace the origins of civil engineering back to it.⁸ Not until after the Seven Years War (1756-1763) and the subsiding of the inflationary period following it did Frederick II and his administrators turn their attention to technical instruction, but at the time military technical instruction took the lead. An *Académie des no-*

7. Rodney Gothelf, «Friedrich Wilhelm I and the Beginning of Prussian Absolutism, 1713-1740», in *The Rise of Prussia, 1700-1830*, ed. Philip G. Dwyer (Essex: Pearson Education Limited, 2000), 60-61.

8. Konrad Levezow, *Geschichte der königlichen Akademie der bildenden Künste und mechanischen Wissenschaften* (Stettin: Liech; Leipzig: Bruders, 1808); Oskar Simon, *Die Fachbildung des Preussischen Gewerbe- und Handelsstandes im 18. und 19. Jahrhundert nach den Bestimmungen des Gewerberechts und der Verfassung des gewerblichen Unterrichtswesens* (Berlin: Heines, 1902), 642-669. Those who view the *Architektonische Lehranstalt* as the forerunner of instruction in civil engineering include Peter Lundgreen, *Techniker in Preussen während der frühen Industrialisierung* (Berlin: Colloquium Verlag, 1975), 18.

bles (*Académie militaire*) opened in 1765 as an institution of more scholarly learning for officers, but instruction very explicitly avoided more difficult subjects; mathematics only went as high as trigonometry and the techniques needed to design fortification; and very little from mechanics or astronomy was taught.⁹ It was soon followed by a *Pépinière von Architekten* in 1771, which was reestablished as the *École de genie et d'architecture* in 1776; it became a military engineering school when it moved to Potsdam in 1788. Instruction in civil engineering at the *École* was weak, and the institute was dissolved in 1807.¹⁰ Of note for civil engineering was the establishment in Berlin of a mining academy (*Bergakademie*), modeled on Freiberg's, in 1770.¹¹

Whereas in France, Spain, and elsewhere in Europe military institutes were the driving forces behind the development of technical education, cross-fertilization between civil and military engineering instruction in Prussia was rare during these main phases of development—at the beginning of the century, after the Seven Years War, and in the 1790s when several applied educational institutes were established. The last decade of the century witnessed a flurry of activity in technical instruction. An *Artillerie-Akademie* was founded and directed in Berlin in 1791 by General Georg Friedrich von Tempelhoff, a talented mathematician who introduced differential calculus into military instruction and who gave the Seven Years War its name.¹² No new military institutes appeared until after 1806 when the reform of military instruction took on a new urgency after Prussia's defeat to Napoleon. Also in the 1790s a series of provincial schools for arts and trades (*Kunstschulen*) were founded in Königsberg, Halle, Breslau, Magdeburg, Danzig and elsewhere. Intended to promote industrial production and good taste in craftsmen, these schools offered instruction in drawing and elementary mathematics, but they often failed to achieve their goals. Rigorously reformed in 1800, these schools tried to mount a more rigorous curriculum, but their clientele—craftsmen and small manufacturers—was simply unsuited for anything above an elementary level. Nothing in the curricula of these *Kunstschulen* suggests that they contributed to technical training in civil engineering.¹³ The same holds for the *Architektonische Lehranstalt*, established as part of the *Königliche Preußische Akademie der Künste und mechanischen Wissenschaften* in 1790; with the introduction of the *Lehranstalt* the parent institution became known as the *Königliche Preußische Akademie der bildenden Künste und mechanischen Wissenschaften*, indicative of its reorientation toward the fine arts,

9. B. Poten, *Geschichte des Militär-Erziehungs- und Bildungswesen in den Landen deutscher Zunge*, Bd. 4, *Preussen* (Berlin: Hofmann: 1896), 26-45.

10. Simon, *Die Fachbildung des Preussischen Gewerbe- und Handelsstandes*, 678; Poten, *Geschichte des Militär-Erziehungs- und Bildungswesen*, 103-112.

11. Hugo Strunz, *Von Bergakademie zur Technischen Universität Berlin, 1770-1970* (Essen: Glückauf, 1970);

12. Poten, *Geschichte des Militär-Erziehungs- und Bildungswesen*, 91-99.

13. Simon, *Die Fachbildung des Preussischen Gewerbe- und Handelsstandes*, 669-677, 682-690.

including architecture. «Mechanical sciences» then dropped from its name in 1809.¹⁴ Instruction at all of these institutions was insufficient, however, to provide the type of training that surveyors and civil engineers needed for competency in the field.

Why the tide turned in the 1790s has to date not been well explained. Several developments coincided in that decade. What we do know is that «architecture», which had been understood classically as embracing both architecture as an art form and all branches of civil engineering, increasingly became a rational and classical art—just as it was taught at the *Architektonische Lehranstalt*. Also in the 1790s, though, leading civil engineers—self-taught, all of them—began to teach civil engineering privately: it was these individuals to whom Frederick William III (r. 1797-1840) turned for the improvement of engineering instruction in Prussia. Their proposal was the culmination of two decades of institutional and geopolitical developments. The result was the *Bauakademie*, Prussia's first institution dedicated to instruction in civil engineering, founded in 1799.

Three decades earlier, during Prussia's reconstruction after the Seven Years War, Frederick II had enacted three measures of consequence for Prussian technical practices. First, as a means of administrative quality control he instituted the *Ober-Examinations-Kommission* (OEK) in 1770. Part of the social movement in Prussia that promoted the development of an educated middle class and deepened its association with reason, the OEK tested and certified candidates in the knowledge-based pre-requisites it deemed necessary for state positions, including surveying, and later, civil engineering. In an era still without formal technical training, the examination ensured that certain minimum standards of learning and practice were met.¹⁵ Second, he legalized the Rhineland rod as Prussia's standard of length for surveying, civilian and military construction, and artillery calculations. Local units of weights and measures had been the norm before then. While the Rhineland rod did not establish complete uniformity, it did permit some degree of standardization in engineering and the building trades.¹⁶ Finally, Frederick II ended the decentralized regional administration of civil and hydraulic engineering projects by establishing in 1770 a special bureaucracy, the *Oberbaudepartement*, for the administration of Prussia's public works projects. Economic development in general, including continued reconstruction after the Seven Years War, especially in the eastern provinces of Prussia, was the primary motivation for the department. No other administrative body at the time played such a large role in shaping and maintaining Prussia's landscape, natural and human-made; had a greater impact on the

14. Simon, *Die Fachbildung des Preussischen Gewerbe- und Handelsstandes*, 679.

15. Joachim Ludwig Zitelmann, «Kurze Darstellung der Geschichte und Verfassung des Königlich Preussischen Ober-Bau-Departments», *SNA* 5.1 (1803): 90-112.

16. «Circular des General-Directoriums an sämtliche Kammern und Kammer Deputationen, Berlin, 28. October 1773: Einführung eines allgemeine Feld- und Baumaßes», *Die Behördenorganisation und die Allgemeine Staatsverwaltung Preussens im 18. Jahrhundert*, ed. Ernst Posner *et al.*, Bd. 16.1 (Hamburg and Berlin: Parey, 1970), 97-98.

physical and aesthetic construction of the state; or did more to reform measuring practices statewide. Before 1770 any project involving measurement in Prussian lands, including civil and hydraulic engineering, assembled its technicians from state and local administrators, the military, and local residents. The *Oberbaudepartement* changed the staffing of projects: henceforth all projects were administered from Berlin.¹⁷

The bureau consisted of a board of ten men, none from the military, who professed an expertise in the construction or management of Prussia's material resources and infrastructure: streets, waterways, mines, mills, civil architecture, mapmaking, surveying, forestry, and fire safety. Prussian civil engineering began to take shape in this bureaucratic context. Its most well-known members included the polymath Johann Heinrich Lambert (1728-1777), the hydraulic engineer and mathematician Johann Albert Eytelwein (1764-1848), and the architect and civil engineer David Gilly (1748-1808). Largely self-educated in mathematics, science, and technology, they also came for the most part from families at the lower end of the economic scale, or from families once well off but now in need of financial security. Eytelwein and Gilly in particular were instrumental in transforming Prussia's technical education, but not until after the three partitions of Poland when the *Bauakademie* was founded. Their experiences in the field, on Slavic soil, played into their understanding of technical education, how they viewed the relationship between the engineer and the state, and even the identity of the Prussian state itself.

Geopolitics, waterways, and the Prussian frontier

By the time all three reforms —administrative, professional, and metrological— were enacted in the early 1770s, Prussia was emerging from the economic recession precipitated by the Seven Years War (1756-1763). Frederick II began to issue grants for reconstruction immediately upon the termination of hostilities, but reconstruction was slow until the end of the 1760s when the state began to recover financially from war-induced inflation.¹⁸ Damage from the war was great all across Prussia, but despite the damage inflicted upon them, the provinces of western Prussia garnered less state attention than those in the east.¹⁹ The choice was strategic.

17. «Instruktion für das Oberbaudepartement», *ABB*, 15:282-91. Silesia was exempt from the practice as a result of agreements reached in 1741 when the province became a part of Prussia, but local authorities often heeded to Berlin on certain matters, especially hydraulic projects. On the *Oberbaudepartement* and the *Bauakademie*, see the excellent study by Reinhart Strecke, *Anfänge und Innovation der preußischen Bauverwaltung: Von David Gilly zu Karl Friedrich Schinkel* (Köln: Böhlau, 2002), and the exhibit catalog, *Mathematisches Calcul und Sinn für Ästhetik: Die preußische Bauverwaltung, 1770-1848* (Berlin: Duncker & Humboldt, 2000), especially Reinhard Strecke, «Prediger, Mathematiker und Architekten: Die Anfänge der preußischen Bauverwaltung und der Verwissenschaftlichung des Bauwesens», 25-36.

18. Hubert C. Johnson, *Frederick the Great and His Officials* (New Haven & London: Yale University Press, 1974), 237-238; Christopher Clark, *Iron Kingdom: The Rise and Downfall of Prussia, 1600-1947* (Cambridge: The Belknap Press of Harvard University Press, 2006), 209-210.

19. Thomas Spohn, «Die baulichen Spuren Preußens in Westfalen», *Westfalen. Hefte für Geschichte, Kunst und Volkskunde* 73 (1995): 95-154.

In contrast to western provinces, which could be likened to an archipelago, eastern provinces were large, contiguous, and laced with rivers that could be added to Prussia's waterway transportation infrastructure.²⁰ For instance, Gilly directed the rebuilding of the fortress city of Küstrin on the Oder and supervised most of the other projects in eastern regions.²¹ In 1769 he directed the lowering of the Madüsee in Pomerania by nine Prussian feet (2.82 meters), which increased the incline of the Plöne River, and yielded land for 700 colonists.²² Two years later supervised the draining of Usedom on the Baltic Sea; 280 settlers later descended. And with the draining of the Plöne River in 1774, 150 families found space to live.

Not long after postwar reconstruction began, tensions in international politics between Prussia, Russia, Habsburg Austria, and the Polish-Lithuanian Commonwealth resulted in further Prussian gains in the east. The Commonwealth, which claimed neutrality in the Seven Years War but allowed Russian troops passage to fight Prussia, found itself at war with Russia over constitutional and religious issues between 1768 and 1772. For some time Prussia had been eyeing Commonwealth lands as a way to unite its western and eastern provinces, and had even begun to take over bordering Commonwealth areas in 1770 and 1771. The end of the war resulted in adjusting the balance of power in Central Europe by dividing Commonwealth lands between Prussia, Russia, and Habsburg Austria. The resulting partitions of Poland—three in all—led to a remarkable expansion of Prussia by the addition of West Prussia and the Netzedistrikt, carved largely out of the Commonwealth's Royal Prussia in 1772, followed by the addition of mainly South Prussia in 1793, and finally New East Prussia in 1795. These eastern provinces constituted the Prussian frontier. With the addition of West Prussia and the Netzedistrikt, Prussia acquired about eighty percent of the Commonwealth's trade, a welcome economic boost that further strained Prussia's multiple systems of weights and measures in spite of having established a common standard of length for land measurement and building projects in 1773. Altogether from the Commonwealth, Prussia acquired 300,000 square kilometers of land and 3.2 million people, raising Prussia's population by almost 60% to 8.7 million.²³ Prussia was more multiethnic

20. W. O. Henderson, *Studies in the Economic Policy of Frederick the Great* (London: Frank Cass & Co., 1963), 75-80; Herbert Moegelin, «Das Rétablissement des adligen Grundbesitzes in der Neumark durch Friedrich den Großen», *Forschungen zur Brandenburgischen und Preußischen Geschichte* 46 (1934): 28-69, 233-274; Benno von Knobelsdorff-Brenkenhoff, *Eine Provinz im Frieden erobert: Brenckenhoff als Leiter des friderizianischen Rétablissements in Pommern, 1762-1780* (Köln: Grote, 1984); GSIA PK, I. HA Rep. 76 (alt) Ältere Oberbehörden für Wissenschaft, Kunst, Kirchen- und Schulsachen IV, Nr. 18, fol. 2v.

21. Marlies Lammert, *David Gilly: Ein Baumeister des deutschen Klassizismus* (Berlin: Akademie-Verlag, 1964).

22. David Gilly, «Fortsetzung der im ersten Bande S.52 abgebrochene Darstellung des Land- und Wasserbaues in Pommern, Preussen, und einem Theil der Neu- und Kurmark», *SNA* 1.2 (1797): 27-29. Eytelwein turned the draining of the lake into a quantitative experimental study: Johann Albert Eytelwein, «Untersuchungen über die Zeit, welche erfordert wird, einen See oder Behälter durch eine oben offenen rechtwinkliche Oeffnung um eine bestimmte Tiefe abzulassen», *SNA* 1 (1797): 79-87.

23. Clark, *Iron Kingdom*, 213. For a near-complete list of colonies, see Udo Froese, *Die Kolonisationswerk Friedrichs der Großen: Wesen und Vermächtnis* (Heidelberg & Berlin: Kurt Vowinckel Verlag, 1938), 120-146.

than it ever had been, and now included Poles, Kashubians, Lithuanians, Belorussians, Ukrainians, and the largest population of Jews in Europe. After the first partition, Frederick II —despite his earlier advocacy of toleration— wanted to reduce the roughly 25,000 Jews in West Prussia to 2,000 by expelling «ragtag Jews». Although he failed to achieve his goal —he managed to expel only 7,000 Jews— he nonetheless maneuvered the greatest diaspora of any group from Prussia since the sixteenth century. After the second and third partitions expulsions were impossible, so assimilating the non-German population became a high priority. West, South, and New East Prussia also included Germans and Dutch who had settled there between the sixteenth and eighteenth centuries, but they were a minority.²⁴

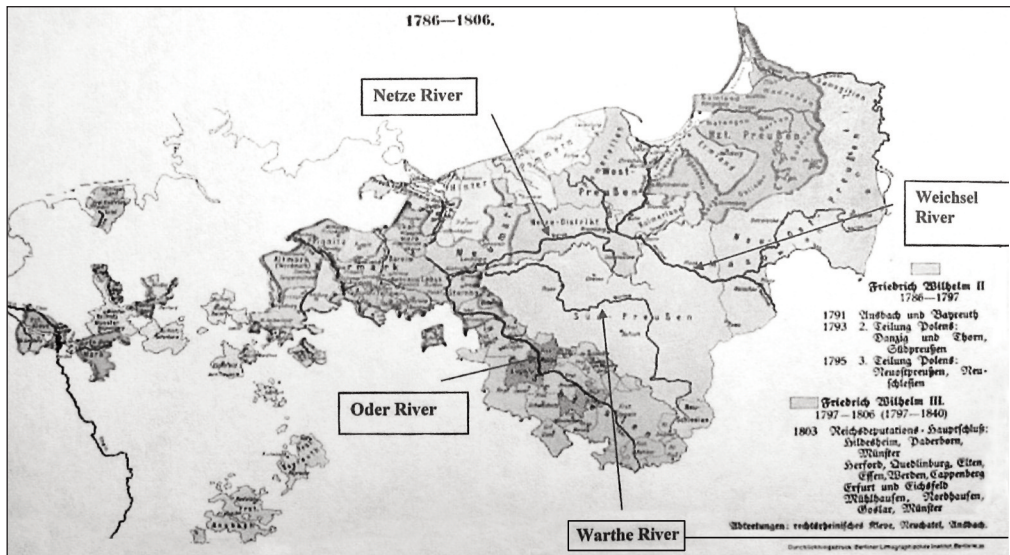


Figure. 3. Major Rivers in the Prussian Frontier: Oder, Netze, Warthe, Weichsel.

Source: Ida Mück, *Atlas zur territorialen Entwicklung Preußens*. (Berlin: Gea Verlag, c. 1900). Karte VII.

Modified digitally by the author

Slavic and Polish Prussia presented formidable administrative challenges. All of these provinces shared a similar geography: flat, marshy land laced with rivers and left with slight

24. William W. Hagen, *Germans, Poles, and Jews: The Nationality Conflict in the Prussian East, 1772-1914* (Chicago: University of Chicago Press, 1980), vii, 5-6, 45-46, 55-65. On the Prussian attempt to establish colonies of Jews, see Jonathan M. Hess, «Sugar Island Jews? Jewish Colonialism and the Rhetoric of ‘Civic Improvement’ in Eighteenth-Century Germany», *Eighteenth Century Studies* 32 (1998): 92-100.

surface irregularities —moraine hills—left by glaciers. Not only did all of this new territory have to be measured— a massive task for the *Oberbaudepartement* whose resources were already strained by post-Seven Years War reconstruction —but the addition of the Netze River in the Netzedistrikt, the Warthe River and all of its tributaries in South Prussia, almost all of the Weichsel River in West, South, and New East Prussia, and the slow-flowing and meandering Narew River, a tributary of the Weichsel River, in New East Prussia— significantly increased the demand for hydraulic engineering in order to expand Prussia's system of water transportation, to take over lucrative Slavic trade routes like the Weichsel, and to unite eastern and western Prussia by connecting Prussia's waterways through strategically placed canals. Reclaimed land also had to be carefully measured for colonists who would settle on it; for it was the intention of Frederic II that most of the land be colonized with Germans, a practice his nephew Frederick William II (r. 1787-97) continued with the second and third partitions.²⁵ In Polish Masuria, for instance, where a new canal network was established and excess water drained off into nearby tributaries or lakes, German-speaking colonists were lured from Württemberg, the Palatinate, and Hessen-Nassau for settlement in new villages where property boundaries were determined by *Oberbaudepartement*-certified surveyors.

This pattern of hydraulic development, land reclamation, and colonization was repeated hundreds of times over in areas acquired from the Commonwealth, pressing the *Oberbaudepartement* and its surveyors into service in a region where the volume and types of hydraulic projects and measurements that had to be executed increased phenomenally in the first three decades of the agency's existence, thus providing an entire generation with crucial experience in the field.²⁶ Slavic and Polish Prussia became not only subject to hydraulic engineering and measurement nearly everywhere, but also for the most part under the direction of the best that the *Oberbaudepartement* had: Gilly and Eytelwein. Eytelwein performed the leveling for draining the Narewbruch and straightening the Narew in New East Prussia, in addition to rectifying the Oder, Warthe, and Weichsel Rivers. He also worked on the East Prussian harbors of Memel and Pillau and the Pomeranian harbor at Swinemünde. Gilly took measurements for the first maps of South Prussia, as he had done years earlier for Pomerania, and supervised the construction of the Danzig and Elbing harbors.²⁷ He continued his earlier reclamation of land along the Netze and Warthe Rivers, producing

25. Hagen, *Germans, Poles, and Jews*, 42-43.

26. For a near-complete list of colonies established after the first partition, see Froese, *Das Kolonisationswerk*, 120-146.

27. Charlotte Bussenius, *Die Preussische Verwaltung in Süd- und Neuostpreussen, 1793-1806* (Heidelberg, Quelle & Meyer, 1960), 190-193, 302-308, 311-315; Erich Neuhaus, *Die Fridericianische Colonisation im Netze und Warthebruch* (Landsberg a. W.: Schaeffer, 1905). Gilly's maps are in the Library of Congress: Special Karte von Sudpreussen, mit allerhöchster Erlaubniss aus der königlichen grossen topographischen Vermessungs-Karte / unter Mitwirkung des Directors Langner, reducirt und herausgegeben vom Geheimen Ober Bau-Rath Gilly ; die Post-Course und Hauptstrassen sind gezeichnet vom ersten Generalpostamts-Registrator Matthias, 1802 u. 1803 ; gestochen von Carl Jättnig in Berlin; Paulus Schmidt sculps. in Berlin.

30,000 hectares suited for 160 villages and 4,000 families. He supervised the draining and rebuilding of Driesen on the Netze, too. The Bromberg Canal linking the Netze and Brahe Rivers was completed in 1774 after eighteen months of hard labor by some six to eight thousand workers. It provided a much-needed trade route from the Weichsel to the Oder and eventually to the Elbe.²⁸ Prussia was linked east to west by engineered waterways.

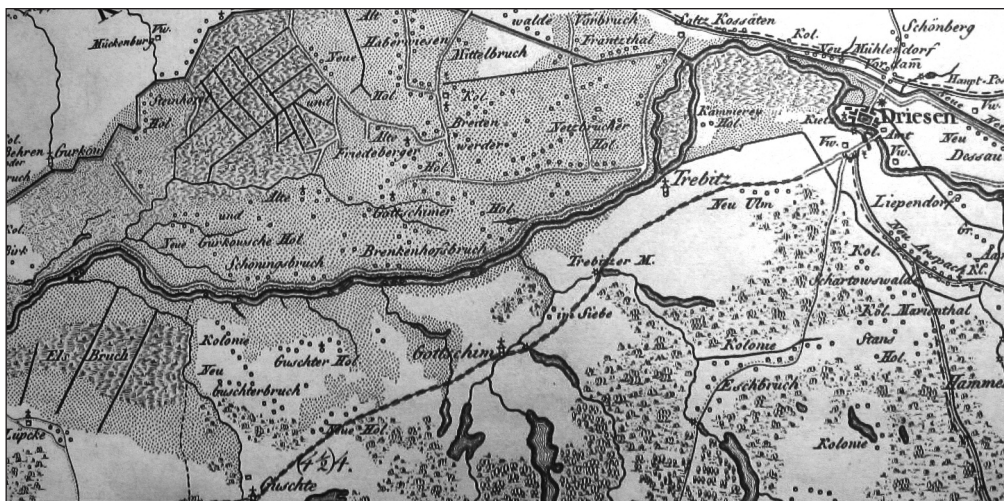


Figure. 4. *The Netzebruch in the Netzedistrikt, with Driesen in the upper right.*

Source: David Gilly's map of South Prussia, section AI. Photographed by the author. Courtesy of the Library of Congress Map Division.

Over vast tracts of land and expansive waterways, Prussian technicians imposed symmetry, regularity, and order in the Slavic- and Polish-speaking eastern provinces to a greater degree than in western ones. Take Gilly's map of the Netzedistrikt, for instance, included with his map of South Prussia. In the marshes of the upper and lower left, the straight lines and geometrical regularity of dams and ditches contrast sharply with the irregularities of the region's natural features, especially the meandering tributaries of the Netze. Geometric grids and technological projects rationalized and tamed waterways and a landscape that had hitherto been called «wilderness» (or whose inhabitants were called

28. W. O. Henderson, *Studies in the Economic Policy of Frederick the Great* (London: Frank Cass & Co., 1963), 80-85.

«barbarians», like the Russians who remained in postwar New Mark).²⁹ Yet more was at stake here than the imposition of technical norms. Introducing Prussian ways of thinking, planning, and even living were just as important as draining land and laying a grid. Eytelwein, when asked to design and construct a brewery and brandy distillery for New East Prussia, refused to take up differences of opinion on how either was made, arguing instead that local traditions had to be given up in the interest of rationally projecting annual production so as to compute the proper size of the facility in preparation for drawing an appropriate architectural plan.³⁰ State-certified surveyors were regularly deployed to integrate Prussian practices into the region, as when they measured forested land in New East Prussia order to stem the use of wood as fuel and building material, already a well-established injunction elsewhere in Prussia.

Christopher Clark has pointed out that Polish Prussia provided conditions for valorizing *preußische Ordnung* with its virtues of orderliness, efficiency, punctiliousness, and precision because it reputedly contrasted so sharply with, and could accomplish so much more than, *polnische Wirtschaft*, Polish [mis]management, identified with chaos, disorganization, waste, laziness, negligence, servitude, and disorder.³¹ Starting with the first partition, Prussian administrators complained of the lack of «industriousness, cleanliness, and orderliness» of Polish subjects, with the result that Prussian rulers insisted on imposing a «Prussian character» on them.³² As a late-century history of Prussia noted of Pomerania: «The organization of this region was quite poor—in a word, Polish».³³ But one has to be careful of taking this prejudicial contrast too far when holding up the ubiquitousness of projects dependent upon hydraulic engineering and measurement in Slavic and Polish Prussia as evidence of the supposedly superior rationalizing impulses of Prussian administrators. The persistent illegal use of local weights and measures in Slavic and Polish Prussia for land measure and construction despite incorporation of lands into Prussian jurisdiction points to the strength of *other* types of rationality in those administrations and economies. The recurring need to produce up-to-date and accurate tables for converting Polish (and other) weights and measures into Prussian ones indicates that even in those areas where the Prussian length was sup-

29. Andreas Kossert, *Masuren: Ostpreußens vergessener Süden* (Berlin: Seidler, 2001), 53; Fritz Terveen, *Gesamtstaat und Retablisement: Der Wiederaufbau des nördlichen Ostpreussen unter Friedrich Wilhelm I, 1714-1740* (Göttingen: Musterschmidt, 1954), 6; Hans Joachim Helmigk, *Oberschlesische Landbaukunst um 1800* (Berlin: Verlag für Kunstwissenschaften, 1937), 192; Herbert Moegelin, «Das Rétablissement des adligen Grundbesitzes in der Neumark durch Friedrich den Großen», *Forschungen zur Brandenburgischen und Preußischen Geschichte* 46 (1934): 31.

30. Johann Albert Eytelwein, *Beschreibung der Erbauung und Einrichtung einer vereinigten Brauerei und Branntweimbrennerei auf dem Land* (Berlin: F. T. la Garde, 1802), 5.

31. Clark, *Iron Kingdom*, 233, and more generally, 230-239, 576-587.

32. Hagen, *Germans, Poles, and Jews*, 39-40, 43.

33. C. G. D. Stein, *Handbuch der Geschichte des preußischen Staats* (Berlin: Friedrich Franke, 1796), 523.

posed to be used, robust local practices —an active form of resistance against Prussian rule— thwarted complete imposition of Prussian norms.³⁴

Yet the impact of having measured so much land and of initiating so many hydraulic projects in these new eastern provinces in a span of about thirty years was not merely a matter of what technical projects did to Slavic and Polish Prussia, but of what Slavic and Polish Prussia did for Prussian hydraulic engineering. Experience gain in the field was far greater in these eastern provinces than anywhere else in Prussia: Slavic and Polish Prussia was the largest area to date over which Prussian technicians plied their skills. More new colonies and large-scale projects —canals, dikes, dams, and so on— were established in eastern provinces than in western ones, so the power of engineering in transforming waterways and the landscape was more visible to residents —and to state officials— and ubiquitously so. Even state surveyors learned considerably from their field experience, not the least of which was how to make certified measurements a part of good state administration. Hydraulic engineering projects in Slavic and Polish Prussia —like the Oderbruch project in Silesia— were nothing less than a training ground for Prussia's first generation of non-military engineers, and the lessons learned there were not forgotten. A developmental template that linked metrical order and public works to colonization in the east persisted, even becoming a model for the Third Reich's aspirations in Eastern Europe were the extermination of Jews and the dispersal of the local population was couched in hydrological metaphors. Slavs were «swamp-dwellers»; the «Slav flood» was a persistent demographical threat before WWI; and the containment of Slavs was referred to as *Eindämmung*, or damming.³⁵

From field work to formal training

One of the most significant and long-lasting consequences of public works activity in the Polish partitions was the transformation of Prussian technical education. Members of the *Oberbaudepartement* had aided in the assimilation of Slavic and Polish lands by using examinations based on apprenticeship experience, not formal training, to certify surveyors' metrical practices, while engineers had learned largely by apprenticeship. The increased pace of public works projects, especially hydraulic ones, provided the impetus for the reform of Prussian technical education. Field experiences after the First and Second Polish Partitions

34. As Eytelwein did in the first edition of his *Vergleichungen der gegenwärtig und vormals in den königlich preussischen Staaten eingeführten Maaße und Gewichte, mit Rücksicht auf die vorzüglichsten Maaße und Gewichte in Europa* (Berlin: Realschulbuchhandlung, 1798). On Polish Prussia, see Karin Friedrich, *The Other Prussia: Royal Prussia, Poland, and Liberty, 1569-1772* (NY/London: Cambridge University Press, 2000).

35. On the hydrological metaphors, see Blackbourn, *Conquest of Nature*, 256. For a parallel story about German forestry practices and geometrical order, see Jeffrey K. Wilson, «Environmental Chauvinism in the Prussian East: Forestry as a Civilizing Mission on the Ethnic Frontier, 1871-1914», *Central European History* 41 (2008): 27-70. The eastern regions first colonized in the eighteenth century became the locus of Nazi imperialism.

prompted a degree of normalization in surveying and hydraulic engineering practices simply as a means to complete multiple projects simultaneously. Immediately following the Second Polish Partition in 1793, Gilly inaugurated, with Eytelwein and others, private instruction in the form of the *Lehranstalt zum Unterricht junger Leute in der Land- und Wasserbaukunst*. Not surprisingly, topics in hydraulic engineering dominated instruction. Their courses constituted Prussia's most comprehensive curriculum in architecture and civil engineering to date, with lectures on mathematics, architecture, statics, hydrostatics, the theory of machines, dike and dam construction, hydraulic engineering, arithmetic, geometry, trigonometry, algebra, surveying, leveling, perspective, and architectonic drawing. Although their institute only lasted until 1795-1796—that is, until just after the Third Polish Partition when many were called into the field again—its success confirmed the prevailing opinion in the *Oberbaudepartement* that more formal steps had to be taken to improve technical instruction in Prussia. Gilly's talented son, the architect Friedrich Gilly (1772-1800), tried to keep momentum on the matter going with the establishment of a private society for young architects in 1798; but his society became only a forum for developing the artistic, not the technical, dimensions of architecture and engineering.

Success in Prussianizing Slavic and Polish regions—in large part the result of *Oberbaudepartement* activity in surveying, colony design, and hydraulic engineering—enhanced the political profile and administrative need of civil servants responsible for it. The absence, then of appropriate institutions for training, particularly given that there were several strong French technical institutions including the new *École polytechnique* established in 1794-1795, became a pressing political matter after Gilly's *Lehranstalt* disbanded. So at the behest of Frederick William III, the *Oberdepartement* board asked Eytelwein, Gilly, and others to write up a plan for an engineering school in 1798. In 1799 the *Bauakademie* opened as Prussia's first formal civilian institute of instruction in broad areas of engineering and architecture. Its faculty came largely from the governing board of the *Oberbaudepartement*, under whose aegis it fell in 1801. And its curriculum followed that of Gilly's earlier *Lehranstalt* and even included instruction in the design and building of villages for colonization, including the determination of how water would be brought to them.

The *Bauakademie*'s curriculum thus had a strong emphasis upon the practical, and measurement was found nearly everywhere: *all* pupils had to take three years of courses in surveying (*Feldmesskunst*), including geometric surveying and leveling, and had to spend three summers out in the field as an apprentice under an experienced surveyor.³⁶ Pupils had to know how to work with surveying and leveling instruments; to manipulate and convert all the weights and measures in Prussia; to measure and divide fields and forests; to construct ditches, dams, dikes, canals, harbors, streets, and bridges (including calculating cost and

36. Heinrich August Riedel, «Nachricht wegen Fortsetzung der allgemeinen Betrachtungen über die Baukunst», *SNA* 2.1 (1798): 107-118.

necessary labor); to design and build whole village complexes for colonists (including determining how water would be brought to them, which involved using the level); to deal with floods, ice, and moving water (including determining its velocity); and to drain land and irrigate it.³⁷ In addition, pupils learned how to take experimental measurements from trials, as in the testing of building materials and devices such as the lightning rod that would yield data to improve the quality of construction. Prussian technicians in the field brought back streams of results and data that could be poured over in the classroom, and there were no results more abundant than those gained in Prussia's eastern frontier. Prussia's geography and natural resources not only entered into the *Bauakademie's* curriculum, but also played into how practitioners defined hydraulic engineering, Prussian style.

In hydraulic engineering at the end of the eighteenth century, French and Dutch engineers led the way in theory. The standard work on the topic was Bernard Forest de Bélidor's *Architecture hydraulique* (1737), which appeared in a Prussian-supported German translation with a foreword by Christian Wolff in 1740-1742. Wolff argued strongly for the union of theory and practice, for one without the other was, in his words, like the blind leading the blind. As was done in France, he urged, in the German states «those who wanted to become engineers had to be thoroughly familiar with theory».³⁸ Yet neither Wolff's imprimatur nor Euler's suggestion that Frederick II's Dutch hydraulic engineers use the work as a guide to constructing the fountains at Sanssouci were sufficient for *Oberbaudepartement* officials to take Bélidor seriously for quite some time.³⁹ They insisted instead on the careful study of local conditions and indigenous practices first, even while acknowledging that hydrological conditions in Prussia were not necessarily unique, and that solutions developed elsewhere might very well work in Prussia.⁴⁰ The French, they thought, had made great progress. But they adopted French theory and practice only so far because the French based their work on Dutch theories, and Dutch conditions were not necessarily Prussian ones; the low areas of Holland were far sandier, sunk below sea level more, and did not have the scarring moraines left by glaciers.⁴¹ As board member Johann Esaias Silberschlag (1716-1791) real-

37. Johann Albert Eytelwein, «Nachricht von der Errichtung der Königlichen Bauakademie zu Berlin», *SNA* 3.2 (1799): 28-40, on 32-35; GStA PK, I. HA, Rep. 96A Geheimes Zivilkabinett (ältere Periode), Tit. 12M, fol. 15.

38. Christian Wolff, «Vorrede», in Bernard Forest de Bélidor, *Architectura Hydraulica, oder die Kunst das Gewässer zu denen verschiedentlichen Nothwendigkeiten des menschlichen Lebens zu leiten* (Augsburg: Klett, 1740-42), unpaginated. A second edition, also with a foreword by Wolff, appeared between 1748 and 1771.

39. The Sanssouci project failed so miserably that there may have been good reason to work with local conditions first rather than imported theories. Dutch engineers, for the most part without the required experience in constructing the massive fountains that Frederick II wanted, managed the project at Sanssouci from 1748 onward, but were not successful until the 1760s. G. Huth, «Verunglückte Wasserwerke in Sans-Souci bei Potsdam», *Allgemeines Magazin für die bürgerliche Baukunst* (2.1) 1792: 78-93.

40. Johann Esaias Silberschlag, *Ausführlichere Abhandlung der Hydrotechnik oder des Wasserbaues*, 2 Bde. (Leipzig: Caspar Fritsch, 1772-73), 2:31-34.

41. «Vorrede», *SNA* 1.1 (1797): iv.

ized in 1772, two years after the founding of the *Oberbaudepartement*, creating order out of disparate practices and far-flung theories would not be easy, but it was necessary to provide a standard other than pleasing external appearances for judging the initial costs and final results of hydrological projects. Dutch contributions, he acknowledged, would presumably dominate, but other results would have to be included in what he hoped would amount to a systematized body of knowledge.⁴² «Theory» for them came to mean the derivation of empirical laws under controlled local conditions, not the laws of hydrodynamics as developed by Euler, the French, and others. «Practice» meant the experience-based techniques and methods that had proven effective in dealing with the Prussian landscape from the Oderbruch project to the partitioning of Poland, not the blanket acceptance of Bélidor's highly regarded hydraulic engineering.

The systematization of hydraulic engineering in the *Oberbaudepartement* thus took on an overwhelmingly local orientation. Places like Uckermark, a «very special province» in the northeast corner of Brandenburg, for instance, were singled out for the hydrological challenges they presented. Named for the Ucke River, a tributary of the Oder, the region had persistent flowing water in the soil not entirely explained by the behavior of its rivers, lakes, lagoons, or the weather, so figuring out how to drain the area was, according to Silberschlag, like solving a puzzle. He noted that windmills similar to those used by the Dutch might work to operate pumps to draw the water to the surface, but they depended on the vagaries of the wind which was «a very uncertain force» that worked «not when it's supposed to, but when it can».⁴³ In a similar vein Eytelwein drew upon his knowledge of the Oderbruch, gained while a dike inspector in Küstrin, as the basis of his textbook on *Faschinenwerke*, a traditional diking technique that resulted in elaborately laced dam-like structures made from natural resources. *Faschinen* were a «flexible» technology based upon weaving together pliable branches, such as willow found locally, that captured sand and silt in the crevices between branches and thereby coaxed nature into finishing the task of creating a firm wall by providing conditions ripe for promoting plant growth. Bundled together in the spring, these *Faschinen* were measured with a ruler, rod, and plumb bob, and the labor required to assemble them carefully calculated. *Faschinen* were considered more effective and less expensive than stones or wood pilings for controlling unwanted flooding, or more importantly, for creating dry land for productive purposes, as both the Oderbruch and Warthebruch projects had demonstrated.⁴⁴

42. Silberschlag, *Ausführlichere Abhandlung der Hydrotechnik*, 1: «Vorrede» (unpaginated).

43. Silberschlag, *Ausführlichere Abhandlung der Hydrotechnik*, 2:6-9, 34.

44. Johann Albert Eytelwein, «Praktische Anweisung zum Faschinenbau und den damit zusammengehörigen Anlagen an Flüssen und Strömen. Nebst einer Anleitung zur Veranschlagung dieser Werke», *SNA* 2.1 (1798): 62-73; Johann Albert Eytelwein, *Praktische Anweisung zur Konstruktion der Faschinenwerke und den dazu gehörigen Anlagen an Flüssen und Strömen nebst einer Anleitung zur Veranschlagung dieser Baue* (Berlin: Friedrich Maurer, 1800).

Silberschlag claimed *Faschinen* came from France, but the technique as well as its characteristic woven pattern became firmly identified with Prussia.⁴⁵ Eytelwein's textbook remained the standard for fifty years, and his method of constructing *Faschinen* could be found all over Prussia.⁴⁶



Figure 5. Constructing *Faschinen*.

Source: Johann Albert Eytelwein, *Praktische Anweisung zur Konstruktion der Faschinenwerke und den dazu gehörigen Anlagen an Flüssen und Strömen nebst einer Anleitung zur Veranschlagung dieser Baue* (Berlin: Friedrich Maurer, 1800), Frontispiece. Photograph courtesy of NSUB.

Empirical knowledge of hydrological practices and indigenous conditions acquired over five decades of field experience as Prussia expanded thus took precedence over imported theories and shaped the *Oberbaudepartement's* understanding of what was necessary in hydraulic engineering instruction. Under the leadership of Gilly and after the Third Partition of Poland, the second generation of *Oberbaudepartement* members created from their experiences a foundation for civil engineering practice and instruction. Following the cessation of private instruction in the *Lehranstalt zum Unterricht junger Leute in der Land- und Wasserbaukunst*, but while they were in the field on former Polish soil, Gilly and Eytelwein started a new journal, the *Sammlung nützlicher Aufsätze und Nachrichten, die Baukunst betreffend, für angehende Baumeister und Freunde der Architectur*, a total of twelve issues in six volumes published between 1797 and 1806. The journal was a preparatory step to creating a compendium of best practices in architecture, civil engineering, and hydrotechnology that

45. Silberschlag, *Ausführlichere Abhandlung der Hydrotechnik*, 2:41. The root of the word *Faschine* is *fascis* (L.) meaning «bundle». Expressed in Italian as *fascio*, it is also the root of «fascist».

46. Gotthilf Hagen, *Handbuch der Wasserbaukunst*, 3 Theile (Königsberg: Borntäger/Berlin: Ernst & Korn, 1841-1867) Theil 2, Bd. 2: 8.

could serve as a reference work for practitioners and instructors. Part of the flurry of journals having relatively short publishing lives but with profound impact on public instruction during the Prussian Enlightenment, the *Sammlung* was not merely or even primarily for architecture, but rather assembled in one place the diverse intellectual, scientific, practical, economic, political, civil, and aesthetic concerns that came to bear on all construction projects: rural and urban, public and private, royal and state. The journal was furthermore a testament to the central role of measurement in all the *Oberbaudepartement* did. Articles in the *Sammlung* as well as the collective publications of *Oberbaudepartement* members attest to the extent of their efforts to express the material world in numerical terms, to standardize measuring practices, and to instigate changes in how state measurement was done and by whom.

Empirical studies demonstrated their commitment to modeling the constructed world in mathematical terms whose dimensions were acquired through measurement. Even though Silberschlag had on occasion expressed antagonism toward *Messkünstler* («measuring artists») for their lack of knowledge of higher mathematics, the complaint wore thin in the years ahead.⁴⁷ Lambert had died in 1777, but his investigations continued to provide the principal model for how to unite measuring practices, empirical data, and theoretical generalizations in *Oberbaudepartement* projects. Until late in the century, members of the *Oberbaudepartement* translated Lambert's earlier works from French into German, repeated his trials, and added new own data to his. Eytelwein did just that with Lambert's study of how fire hoses could be used to maximize the effect of water while minimizing the fatigue of firefighters, as did Heinrich August Riedel (1748-1810) with Lambert's windmill trials where he transformed Lambert's data into empirical equations, hoping to discover a way to maximize a windmill's power, an exercise in part motivated by the department's desire to minimize costs while maximizing effects.⁴⁸ This exercise, in turn, led them to consider the quality, meaning, and value of data more deeply, as Lambert had done, and to explore the significance of the graphical analysis of data, a technique Lambert had pioneered after learning of the more widely used graphical representation of barometric data.⁴⁹

Stationed as a dike inspector in Küstrin on the Oder and preparing for his state examinations early in his career, Eytelwein explored the significance of water level measurements—he had access to about twenty-five years of data—by representing them graphically. What troubled him about tabular data was that it was difficult to draw conclusions from them, whereas when placed in a graphical format as were frequently done with barometric

47. Silberschlag, *Ausführlichere Abhandlung der Hydrotechnik*, 1:xvi.

48. «Lamberts Tabelle der besten Dimensionen der Feuersprützen, dennoch mit einer Kolumne vermehrt vom Geh. Oberbaurath Eytelwein», *SNA* 1.2 (1797): 105; «Versuche und Bemerkungen über die unterschlächtigen Mühlen, vom Herrn. Prof. Lambert, übersetzt durch Heinrich Riedel», *SNA* 1.2 (1797): 110-126.

49. As he did in Johann Heinrich Lambert, *Hygrometrie oder Abhandlung von den Hygrometern. Aus dem Französischen übersetzt*. (Augsburg: bey Eberhard Ketts sel. Wittib., 1774)

measurements, one could see patterns «at a glance». With Rhineland feet as his vertical measurement, and years, months, and 10-day intervals within months as his horizontal markers, he represented the ebb and flow of the height of the Oder.

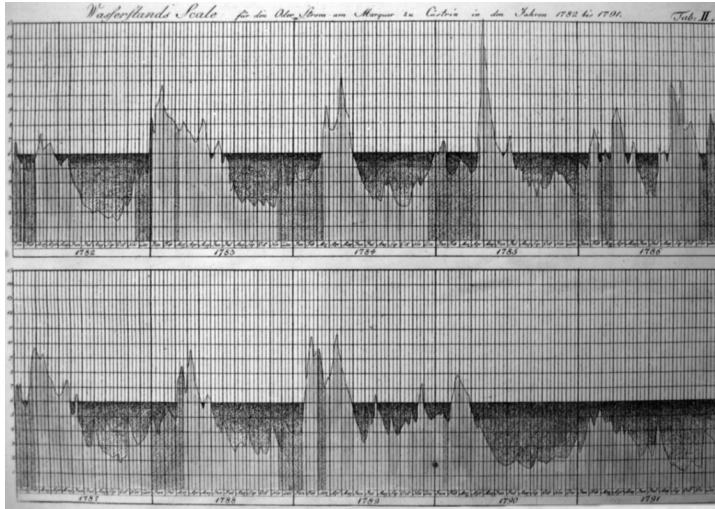


Figure 6. *Water Levels of the Oder, 1782-1791.*

Source: Johann Albert Eytelwein, «Von dem Nutzen einer Wasserstandsscale, nebst Anweisung zur Verfertigung derselben», *SNA* 2.1 (1798): 25-28, Tafel II. Photographed by the author. Courtesy of NSUB.

His most significant generalization —crucial for predicting floods— was that not only did higher than normal water levels follow periods of freezing, but also that flood height (spikes on the graph) was directly correlated to the duration of freezing (darker shades below the curved line).⁵⁰

Nearly everywhere practical problems alimanted science rather than the reverse. The persistence of flooding vexed Prussian engineers, but empirical data on water tables in crucial locations, they thought, might reveal a pattern that could be used as the foundation of flood prevention and control, as Eytelwein had done for Küstrin. Eytelwein also took up difficult topics in hydrodynamics, such as determining the velocity of the flow of water through an apparatus submerged in water, an experiment that fell short because he was unable to develop a general theory of resistance in a fluid.⁵¹ There was at the time no rigorous theory of waves, but they attempted nonetheless to determine analytically the curve of a wave, and from there to figure out

50. Johann Albert Eytelwein, «Von dem Nutzen einer Wasserstandsscale, nebst Anweisung zur Verfertigung derselben», *SNA* 2.1 (1798): 25-28.

51. Johann Eytelwein, «Versuch mit dem Stromquadranten, in Beziehung auf die Bestimmung der Geschwindigkeit der Flüsse, nebst Vergleichung der Theorie mit diesen Erfahrungen». *SNA* 3.1 (1799): 53-74.

exactly what dike curvature would hold up best against crashing waves.⁵² The cumulative impact of Eytelwein and others in the *Sammlung* (and other related publications) was considerable: they accentuated the notion that environmental phenomena were mathematically regular and could be made accessible through measurement; they recast fieldwork based on personal experience as quantified, systematic knowledge; and they applied their knowledge to the training of the next generation of Prussian hydraulic engineers who, like them, dealt with real conditions through approximation formulas based on empirical results. Everywhere *Prussian* conditions shaped their understanding of hydraulic engineering.

What began as an attempt to systematize primarily Dutch theory and practice ended up with a distinctly Prussian stamp. When Gilly began in the mid-1790s to assemble an outline for a lecture course on hydraulic engineering for the *Oberbaudepartement*, he considered local conditions to be sufficiently different from elsewhere to single out Prussia as having a special place in hydraulic engineering. As he explained in 1795 at the moment when Prussia attained its widest geographical expanse to date and had finally acquired the contiguous land bridge to East Prussia that Frederick II had wanted:

The state of our country compels us to pay great attention to the course of currents. Our rivers flow with great strength from the mountains, and our northern climate means we have to worry at certain times about large amounts of ice and snow. We therefore have to make artificial dikes which we must protect from the onslaught of floods with the greatest of care because behind the dikes are created the most flourishing environs (like the Oderbruch, the Wartebuch, the low-lying areas by the Weichsel and Elbe [Rivers], and in other areas). For these reasons our country is a not insignificant showplace of hydrotechnology, where the person eager for this kind of knowledge finds multiple opportunities to develop the theoretical principles of this science from practice, and then to apply them.⁵³

Dutch hydraulic projects, he believed, could not be used as models for Prussian ones because Holland was «protected from the stormy sea in ways we don't find here [and] because in Holland rivers have a very low grade», resulting in river currents much slower than Prussia's and therefore much easier to manage.⁵⁴ So when he and Johann Eytelwein published their textbook on hydraulic engineering in the early 1800s for instructional use at the *Bauakademie*, they continued to integrate local experience into mostly foreign theories and practices, including in

52. Schlegel, «Über das Profil der äussern Abdachung der Seedeiche», *SNA* 1.2 (1797): 70-77.

53. David Gilly, *Grundriss zu den Vorlesungen über das Praktische bey verschiedenen Gegenständen der Wasserbaukunst* (Berlin: Kgl. Hof-Buckdruckerey, 1795), 6.

54. David Gilly, «Kurzgefasste Darstellung der vorzüglichsten Gegenstände der Land- und Wasser-Baukunst in Pommern, Preußen, und einem Theil der Neu- und Kurmark», *SNA* 1.1 (1797): 26-52, on 27.

their exposition the most enduring technologies of other nations «only so far as they are applicable» to Prussia.⁵⁵ The second edition of their textbook included several simple approximation formulas based on empirical studies, and in addition addressed the cost effectiveness of using the steam engine, which had by then become more common in hydraulic engineering, though by no means everywhere. Mindful of the economic frugality that characterized most Prussian public works projects, they recommended extreme caution before deploying it due to the initial outlay for the machine and the subsequent high cost of fuel and repairs.

Eytelwein, who had produced the second edition alone after Gilly's untimely death in 1808, in addition wrote three handbooks —on the mechanics of solid bodies and hydraulics, on the statics of solid bodies, and on hydrostatics— all for pupils of the *Bauakademie* in which he avoided calculus and higher analysis. Although all three were designed «with special consideration of their application to architecture», the volumes were actually intended more for hydraulic and civil engineers. His texts offered a comprehensive coverage of the mechanics, statics, and hydrostatics of solid and liquid bodies based on the analysis of forces, and included applications to bridges, canals, water wheels, and pumps; to the flow of water in compound pipes (as in water fountains, such as at Sanssouci); and to the empirical determination of the velocity of currents. (The latter two were still regarded as especially difficult undertakings). In addition to integrating contemporary theoretical literature, he included his own trials and the laws he derived from them.⁵⁶ For the testing of new machinery, such as a hydraulic ram pump Gilly brought back from Paris, he worked with local instrument makers and strove for the «greatest accuracy» [*Genauigkeit*] in his data by repeating trials several times when ambiguities arose in the most difficult measurements, such as in the measurement of time.⁵⁷ It is worth recalling in this context that Eytelwein was

55. David Gilly and Johann Albert Eytelwein, *Praktische Anweisung zur Wasserbaukunst, welche eine Anleitung zur Entwerfung, Veranschlagung und Ausführung der am gewöhnlichsten vorkommenden Wasserbaue enthält*, 4 Bde. (Berlin: Auf Kosten der Verfasser, 1802-08), 1:10. The authors cite Dutch, French, German, English, Swedish, Swiss and Austrian sources in their bibliography, which was intended for pupil reference, including several textbooks developed for or used in courses at the *Bauakademie*: Eytelwein's *Handbuch der Mechanik fester Körper und der Hydrotechnik: mit vorzüglicher Rücksicht auf ihre Anwendung in der Architektur* (Berlin: Lagarde, 1801), Wencelaus Johann Gustav Karsten's *Lehrbegriff der gesammten Mathematik*, 2nd ed., 2 Theile (Greifswald: Roese, 1778-1786), and Bernhard Friedrich Mönnich's *Lehrbuch der Mathematik*, 2nd ed., 2 Bde., (Berlin: Lange, 1800-1801). Despite those citations, practices developed for Prussian conditions dominate their presentation.

56. David Gilly and Johann Albert Eytelwein, *Praktische Anweisung zur Wasserbaukunst, welche eine Anleitung zur Entwerfung, Veranschlagung und Ausführung der am gewöhnlichsten vorkommenden Wasserbaue enthält*, 4 Bde., Zweite Auflage (Berlin: Realschulbuchhandlung, 1809-1824), 2:46, 3:101; Eytelwein, *Handbuch der Mechanik fester Körper und der Hydraulik*; Eytelwein, *Handbuch der Statik fester Körper: mit vorzüglicher Rücksicht auf ihre Anwendung in der Architektur*, 3 Bde. (Berlin: Realschulbuchhandlung, 1808); Eytelwein, *Handbuch der Hydrostatik: mit vorzüglicher Rücksicht auf ihre Anwendung in der Architektur* (Berlin: Reimer, 1826).

57. Johann Albert Eytelwein, *Bemerkungen über die Wirkung und Vortheilhafte Anwendung des Stoßhebers (Bélier hydraulique): nebst einer Reihe von Versuchen mit verschiedenen Anordnungen dieser neuen Wasserhebungsmaschine* (Berlin: Realschulbuchhandlung, 1805).

self-taught, so the configuration of his hydraulic engineering bore the trademarks of his own longstanding concerns: the special problems of hydrology in Prussia and the peculiarities of Prussian standards. While Eytelwein's work in the field had contributed to the physical construction of the Prussian state, especially its waterways, his textbooks and handbooks shaped the analytical approach a generation of engineers took toward those problems.

The massive task of transforming the landscape was possible only to the degree that measuring practices yielded data appropriate for implementing technical solutions, and in hydraulic engineering, there was no measurement more important than determining if, how, and where water would flow. Here, too, in leveling practices, Prussian hydraulic engineers took local conditions into account. Appropriately the title page to Silberschlag's text on hydrotechnology depicted Athena with a surveyor's pole (*Meßlatte*) standing next to Poseidon, seated and tamed rather than blowing up a storm, resting on a large pipe through which water flowed placidly. Cattails to the right appropriately place the illustration in marshland, a dominant feature of Prussia's landscape.



Figure 7. *Frontispiece to Silberschlag's textbook on hydraulic engineering.*

Source: Johann Esais Silberschlag, *Ausführlichere Abhandlung der Hydrotechnik oder des Wasserbaues*, 2 Bde. (Leipzig: Caspar Fritsch, 1772-73), 1: Frontispiece. Photographed by the author. Courtesy of NSUB.

Especially on flat land that determination was difficult because differences in elevation could be so slight that even small errors would doom a project; worse, errors compounded over long distances. Time after time inaccurate leveling was cited as the prime reason for

failure in hydraulic engineering.⁵⁸ Assuring accuracy in measurement was thus a prime desideratum. But how could accuracy be achieved? What degree of accuracy was necessary in practice? What was meant by accuracy in leveling? Unlike manuals on leveling from the Kingdom of Hanover or the areas around Nürnberg and Augsburg where there were skilled metal workers and mechanics adept at perfecting instruments, Prussian manuals on leveling from the second half of the century did not focus on artisanal perfection. From the Oderbruch project onward there was in Prussia a downright suspicion of compound instruments, from Humbert's manual on leveling of 1750 to Gilly's in 1801. Humbert, who had rejected Picard's treatise on leveling as too complicated, instead advocated balancing instruments, even imperfect ones, with the particular purpose for which they were to be used.

I, for my own part, am assured that the instrument that is less compound is also least subject to errors. Even if a mechanic has erred only a little in the division of degrees and minutes —say if the error is only barely that of a hair— then an error in the final result will be noticeable, and will grow in proportion to the distance. So the instrument that is less compound remains all around the best in practice. The bad measuring table, if used properly, is very convenient for the mapping of streets in a large city; the magnetic compass is useful for the mapping of large forests; and the rod is serviceable for the mapping of farmland in fields that have drainage ditches.⁵⁹

Some other instruments, he continued, were too difficult to use, cost too much, or could not always be constructed or repaired by mechanics. Insistent that leveling measurements had to be accurate [*accurat*], Humbert worked around instrumental imperfections by showing how the most reliable results in leveling, those taken over a short distance, could be summed up to cover a longer distance through a properly chosen protocol.⁶⁰

While leveling instruction at the *Bauakademie* was for the most part practical, but it drew heavily upon theoretical investigations conducted by Lambert who had explained so eloquently why one leveling instrument was better than another for particular tasks and why accuracy in leveling was so important —and different— in Prussia. He drew upon his practical experience in the field to explain the nature and quality of leveling instruments in a republication of Passavant's translation of Picard's treatise that appeared in 1770 —right in the midst of reconstruction after the Seven Years War and of the metrological, administrative, and professional reforms that changed Prussian surveying and engineering practices. The appearance of the volume underscored the centrality of careful geometric leveling to *Oberbaudepartement* technicians.⁶¹

58. E.g., as for Sanssouci, Huth, «Verunglückte Wasserwerke», 80.

59. Humbert, *Neue Anweisung zum practischen Gebrauch des Nivellirens*, 10-11.

60. Humbert, *Neue Anweisung zum practischen Gebrauch des Nivellirens*, Plate II, Fig. 4.

61. «J. H. Lambert's Beyträge zum Wasserwägen», in Jean Picard and Johann Heinrich Lambert, *Picards Abhandlung vom Wasserwägen mit einen Beyträgen von J. H. Lambert* (Berlin: Haude und Spener, 1770), 187-256.

Lambert's reasoning on accuracy and reliability in leveling was anchored in the knowledge of local conditions in Prussia. His persistent attention to geographical conditions, specifically to leveling on flat land in comparison to the same in hilly or mountainous regions, embedded his scientific discussion in the particular rather than the general. He described the problems of leveling in circumstances that characterized large portions of Prussia: either flat and sandy land, such as in Brandenburg; marshy land where the water table was high, such as the Oderbruch; or land where underground currents and streams were numerous and where river currents either were very slow or varied markedly, such as in Pomerania.⁶² These hydrological conditions were difficult to handle, Lambert pointed out, because so few experimental trials on them had been done, and there was a dearth of data to analyze. Nonetheless, the gross features of the Prussian landscape convinced him that when leveling in Prussia, one had to make special demands on the quality of the measurements and on the type of instrumentation used. Why? The errors in measurement had to be *less* than the very small differences in elevation that characterized relatively flat land. By contrast, leveling in foothills and mountains, as occurred in large parts of southern Germany, was an entirely different matter. When the elevation changed noticeably one could have «a greater degree of unreliability» in measurements and still get reasonably good practical results.⁶³ And just as the range of permissible error differed from north to south, so did the type of instrumentation. Some leveling instruments were just too unreliable to be used in Prussia, such as the barometer and the plumb bob, because the measurements they yielded were simply not refined enough.⁶⁴ That did not mean one should stop using either; a barometer, for instance, was eminently suited for measuring mountain elevation, as Cassini demonstrated for the Pyrenees; but with an accuracy of only $\frac{1}{2}$ *Linie* [1.09 mm], it was unsuited for conditions where the difference in elevation was a single *Zoll* [2.615 cm].⁶⁵ Lambert's discussion was the first of many in Prussia to link measuring practices to geographical location and to claim that leveling accuracy was more critical in the north than it was in the south.

So even though Lambert claimed he was «concerned not with leveling [on flat ground] alone» but in more general terms, «as one does when measuring height, especially of distant mountains, where one demands less accuracy [*Genauigkeit*] than in leveling proper», his overriding concern was with leveling on conditions like those in northern and eastern Prussia.⁶⁶ He proffered the communication tube (hydrostatic level) as the most convenient and reliable level for use on flat land. He suggested simply using a long fire hose or flexible

62. «J. H. Lambert's Beyträge zum Wasserwägen», 200-201.

63. «J. H. Lambert's Beyträge zum Wasserwägen», 197-198, on 198.

64. «J. H. Lambert's Beyträge zum Wasserwägen», 205, 217.

65. Johann Bernoulli, ed., *Johann Heinrich Lamberts deutscher gelehrter Briefwechsel*, 4 Bde. (Berlin: Bey dem Herausgeber), 1782-1784), 4:23.

66. Bernoulli, *Lamberts deutscher Briefwechsel*, 3:169.

tube to which open glass tubes, with marked divisions, were attached at both ends, and the entire arrangement filled with water. With this device, he argued, one could measure the change in elevation over a distance of a hundred feet or more without consideration of the errors stemming from either the curvature of the earth or the refraction of air, both of which were canceled out and hence had no effect on readings. And the small uncertainty of $\frac{1}{4}$ to $\frac{1}{2}$ *Linie* [.545 to 1.09 mm] that arose from reading the level of the water in the tubes could be compensated. The communication tube enabled, he claimed, an «art of leveling» that was «very simple». It had the added advantage of compensating automatically for small errors «because in estimating the surface of the water one sometimes does so too much and then too little», so errors just cancelled each other out.⁶⁷ By contrast, with other more common methods of leveling such as with a plumb line or barometer, «it is difficult, if not impossible, to be so accurate».⁶⁸ For that reason he believed that complex geographical sites such as the Oderbruch would never yield «geometrical sharpness» in leveling. Hence in 1770 he lamented: «One will probably never measure the elevation of the entire length of the Oder from its source to the sea with a level of any type».⁶⁹

When David Gilly assembled his instructional handbook on leveling for *Bauakademie* classes on leveling in 1801, he aimed it not at operations that depended on «hairsplitting accuracy (as is needed, for example, in the design of mills, canals for shipping, etc.)» but rather at projects like those he supervised in Prussia's newly acquired eastern provinces where ditches had to be drained, peat bogs dried, and elevation profiles had to be calcu-

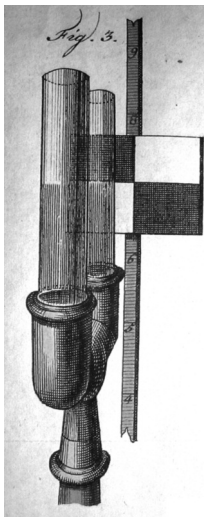


Figure 8. A communication tube or hydrostatic level set against a surveyor's pole.

Source: David Gilly, *Praktische Anleitung zur Anwendung des Nivellirens oder Wasserwägens in den bey der Landeskultur vorkommenden gewöhnlichsten Fällen* (Berlin: Realschulbuchhandlung, 1801), Tab. I, Fig. 3. Photo courtesy of NSUB.

67. Bernoulli, *Lamberts deutscher Briefwechsel*, 3:166; «J. H. Lambert's Beyträge zum Wasserwägen», 203.

68. «J. H. Lambert's Beyträge zum Wasserwägen», 202-204, on 204.

69. Bernoulli, *Lamberts deutscher Briefwechsel*, 4:23. 306.

lated.⁷⁰ Inspired by Lambert's principles, Gilly recommended using the hydrostatic level or communication tube because it worked best on relatively flat land.

This quick and reliable solution to enhancing leveling practices was needed, he pointed out, because of «the ever-rising cultivation of the land» in Prussia that had far outstripped the available supply of surveyors and engineers. Melioration of the marshy, lake-dotted and flat regions of Masuria acquired in the Second and Third Polish Partitions was both an economic necessity and political imperative, he explained, where

more and more ditches, dams, locks, and such are planned in order to drain the land; many lakes and marshes are drained in order to create usable ground. In particular many trenches are built in order to dry out sections of peat so that it could be used as a substitute for wood, ever declining, as fuel. Also trenches serve for the draining of water in the overgrown sections of forests in order to promote the growth of trees for wood, a practice that follows the admirable example of many private owners.

Gilly believed, however, that these private practices —guided, to date, by rules of thumb— could be improved considerably by determining the gradient of the land by leveling before projects began; otherwise «the work is conducted haphazardly, not infrequently expenses become wasteful, and what is probably by far the worst, the work becomes purposeless and probably entirely in vain». He had even grander reasons for promoting accurate leveling, ones consistent with the type of aesthetic, geometric regularity that had been popular at the beginning of the century; for in addition to promoting use of the communication tube among pupils at the *Bauakademie*, he also wanted bricklayers, carpenters, stone masons, and those who worked on dams to use it because it was less error-prone than a plumb bob and resulted in a more regular appearance overall.⁷¹

So as much as Prussia's technicians of measurement sought ever greater accuracy in leveling, ease of measurement and the reliability of results proved to be more important desiderata. From a historical perspective, however, the introduction of Picard's treatise on leveling into Prussian hydraulic engineering at two crucial points —first in 1749 during the Oderbruch project and later in 1770 during a period of post-war reconstruction and administrative changes leading to the centralization and regulation of measurement— accentuated the importance of leveling as one of the most important venues for exploring accuracy in measurement. In Prussian contexts, however, local problems sometimes trumped

70. David Gilly, *Praktische Anleitung zur Anwendung des Nivellirens oder Wasserwägens in den bey der Landeskultur vorkommenden gewöhnlichsten Fällen* (Berlin: Realschulbuchhandlung, 1801). Quote is from an advertisement for Gilly's handbook, *SNA* 6.2 (1806): 137.

71. Gilly, *Praktische Anleitung zur Anwendung des Nivellirens*, 4. Nearly all of Gilly's instructions applied to relatively flat and water-logged land.

the implementation of the means to achieve greater accuracy. Lambert's elaboration on Picard was not about attaining the more extreme degrees of accuracy that refined instrumentation might allow, but rather about achieving the kind of accuracy that surveyors could reasonably be expected to achieve in the field while satisfying the demands of economic efficiency and mechanical safety that state officials mandated and the public expected.

Geopolitics, the state, and the engineer

More than any other administrative unit in Prussia before 1806, the *Oberbaudepartement* became the locus of a technical bureaucracy that strongly linked mathematics, measurement, and engineering to the state's interests, especially in economics, demographics, and—to the degree that land reclamation, canal-building, and reconstruction were also the «Prussianization» of a region—also culture. Indeed the double mission—technical and cultural—became ever more important as Prussian engineers moved eastward from Silesia to New East Prussia. When we ask how order came from disorder, identity from diversity, and tamedness from wilderness, we cannot avoid considering the decisive roles of measurement, geometry, and engineering. All were means of control, integration, and standardization. As Henning Eichberg has argued, «[r]egularity, uniformity, and standardization were the socio-structural norms and features of early modern state-building».⁷² Yet what was their position vis-à-vis the state of this first generation of technical advisors in Prussia?

That Prussian conditions loomed large in the knowledge that defined their expertise could be read as an expression of their perceived indispensability to the Prussian state and its projects. Eytelwein, writing on the *Bauakademie* in 1799, urged that it was imperative to «rise above» the «prejudicial separation» of theory and practice in order to create an institute where both could be combined so that neither aesthetics (which did not address the physical feasibility of a project) nor the scientific or theoretical (which went «too far in the direction of mathematical abstraction, without the appropriate consideration of locality») dominated. He viewed the attainment of that balance as necessary for the good management of Prussia's economy: with so much built at royal cost, it was essential not to waste money on projects with insecure foundations.⁷³ Bundling theory, practice, and cost together as he did tells us why others such as Riedel believed that foreigners—specifically the French and the English—could not solve Prussia's problems: they lacked knowledge and acquaintance with local conditions and moreover they worked in different economic conditions, often with private entrepreneurs, which Prussia, he claimed, did not have.⁷⁴ Much as instruction

72. Henning Eichberg, *Festung, Zentralmacht und Sozialgeometrie: Kriegingenieurwesen des 17. Jahrhunderts in den Herzogtümern Bremen und Verden* (Köln: Böhlau, 1989), 421, 424-25.

73. Johann Albert Eytelwein, «Nachricht von der Errichtung der Königlichen Bauakademie zu Berlin», *SNA* 3.2 (1799): 28-40, on 28, 29.

74. Heinrich August Riedel, «Fortsetzung der allgemeinen Betrachtungen über die Baukunst», *SNA* 1.2 (1797): 3-17, on 15-16.

was expensive for the state, Riedel argued, it was less costly than error-laden ventures, a lesson he drew after reviewing the ill-fated Finow Canal project.⁷⁵ Those who designed and built Prussia thus assumed responsibility to secure and uphold the fiscal health of the state, and in so doing, placed themselves in a position of strategic importance to its proper maintenance.⁷⁶

Far more significantly, perhaps, they used their assembled knowledge to articulate Prussia's identity. For members of the *Oberbaudepartement*, to define hydrotechnology at the end of the eighteenth century was to define Prussia on the basis of its geography —not as a geopolitical map would depict it, but according to the predominant forces of nature acting on it and the technical means used to control them. Experiences in the new eastern provinces were crucial here. Others acknowledged the success of their tactic. In 1780 the well known and highly respected Hanoverian military engineer, Johann Ludwig Hogrewe (1737-1814), took note of the accomplishments of Prussian hydraulic engineers in building canals which by then had created a mesh linking Prussia's rivers sufficiently widespread to support inland transportation as well as travel to the Baltic and the North Seas. Quoting Anton Friedrich Büsching's *Wöchentliche Nachrichten*, a Berlin-based weekly covering topics of interest to cameralists, Hogrewe remarked: «No other country in Germany has attained through sovereign foresight so many conveniences for internal and external travel by means of ships than Mark-Brandenburg».⁷⁷ He not only cited the Finow, Oder, and new Bromberg canals, but also those that promoted trade with places like Lithuania, including the canals on smaller rivers, like the Pregel. To a certain degree, these ubiquitous but now surmountable hydrological challenges constituted the state-wide commonality that Prussia's ethnic, linguistic, cultural, and religious diversity could not yet provide: they characterized an important dimension of the shared collective life of individuals living on the Prussian section of the North European Plain; they constituted the common cause of what encumbered Prussians and their government in so many ways; and their melioration gave visible material expression to the state's power to transform the landscape through the implementation of technical solutions believed to contribute to the common good.

Throughout Europe, engineers of the period bespoke a utilitarian ethic. Prussian utility had a twist. Technicians' experiences in the eastern provinces taught them that solutions to hydro-technological problems were likewise solutions to socio-economic ones: marshes, bogs, and swamps were quite simply unproductive soils that kept living conditions at

75. Riedel, «Fortsetzung», *SNA* 1.2 (1797): 13.

76. Joachim Ludwig Zitelmann, «Kurze Darstellung der Geschichte und Verfassung des Königlich Preussischen Ober-Bau-Departments», *SNA* 5.1 (1803): 90-112, on 97, 94-95, 91.

77. J. L. Hogrewe, *Beschreibung der in England seit 1759. angelegten, und jetzt größtentheils vollendeten schiffbaren Kanäle* (Hannover: H. M. Pockwitz, 1780), 43. Mark-Brandenburg here designated the seat of the state government, not the location of the canals, which of course stretched across all of Prussia.

poverty levels. Their attitude toward the natural world was that it was a job left undone, constantly threatening to revert back to a state of wilderness.⁷⁸ Land that was inaccessible to human footsteps «served only to house wild animals».⁷⁹ Civil engineering was their agent of civilization, rescuing a people from wilderness by creating the conditions for realizing the happiness, morality, and well-being of all classes, «especially the needy and working classes» who required «constant protection against general poverty, dissatisfaction, and immorality». Without civil engineering, society would simply revert into the condition of «irrational animals» and would «enter wilderness» again.⁸⁰ Thus the implementation of material technologies was thus just as much about achieving social stability as it was about transforming the natural world, as their hydrological projects in Slavic and Polish Prussia illustrate. Like the ubiquitous local societies that promoted Prussian economic development by combining the resources of natural philosophy, technology, economics, and statistics, such as the Royal East Prussian Physico-Economical Society or the Mark Economic Society in Potsdam, members of the *Oberbaudepartement* worked with the same tools and had the same goals, but did so on a state-wide scale and with financial resources that dwarfed local efforts. They were like an infantry marching across the landscape, shaping the material conditions for implementing the royal or ministerial economic initiatives that were supposed to create a state of culture and civilization.

Their textbooks and writings linked hydraulic engineering, and with it, measurement, to social and economic improvement, and so to the opposite of wilderness: civilization. Silberschlag chose for his textbook the problems that occurred most frequently in Prussia because «their solutions have the greatest influence on the needs of common life».⁸¹ Uckermark once again was a special case: «The poverty, which hangs over the entire province due to frequent and persistent rainfall, is so terrible that one should consider how to solve this problem in a timely fashion», he urged, likening this and similar problems to illnesses that had to be cured for the state to be healthy.⁸² In a similar vein Gilly and Eytelwein insisted thirty years later on making the most common Prussian hydraulic practices public «for the satisfaction of the needs of civil society», for the state's economic well-being, and for protection against the overwhelming forces of nature, especially water and ice.⁸³ Although Johann Samuel Lilienthal (1723-99) found that making the Memel Harbor assume its planned

78. David Gilly, «Fortsetzung der im zweyten Band S. 36 abgebrochenen Darstellung des Land- und Wasserbau in Pommern, Preußen und einem Theile der Neu- und Kurmark», *SNA* 2.1 (1798): 3-10, on 4, 5.

79. Joachim Ludwig Zitelmann, «Über den Nutzen der Wiesen-Wässerung, und die verschiedenen Wässerungs-Anstalten älterer und neuer Zeiten», *SNA* 1.1 (1797): 128-154, on 128.

80. Heinrich August Riedel, «Allgemeine Betrachtung über die Baukunst», *SNA* 1.1 (1797): 1-25, on 6, 12, 20.

81. Silberschlag, *Ausführlichere Abhandlung der Hydrotechnik*, 2: iv.

82. Silberschlag, *Ausführlichere Abhandlung der Hydrotechnik*, 2: 35, 41.

83. Gilly & Eytelwein, *Praktische Anweisung zur Wasserbaukunst*, 1:9.

dimensions was fraught with difficulties, he nonetheless persisted because «one must spare no effort and risk because the lives of the people and the security of shipping depend on it».⁸⁴ For Riedel construction was to the state what medicine was to the body, thereby implicating construction of all types in state-building. Epistemologically, they were also alike: «Both had to create theories out of many experiences led by analogy in order to make use of similar means in similar circumstances to ensure similar effects».⁸⁵

Teachers of the public and servants of the state, Prussian technicians affected social change through «moral» instruction, thereby making themselves indispensable to the attainment and maintenance of the general welfare of the state. Antoine Picon and Ken Alder, both historians of French Enlightenment engineers, have identified the use of such rhetoric as legitimating strategies. Projecting compassion, in Picon's view, is a «strategy of power»: it enables control over the less fortunate and distancing from the less trained, especially artisans.⁸⁶ In his discussion of French artillery engineers, Ken Alder deftly explained how they were able to tie epistemological and social concerns together (he called it a «social epistemology») to make «expertise» a code for living. Prussian technicians did much of the same. But where Alder saw the production of the self-disciplined individual, both molded and assessed by the impersonal standards of judgment mathematical training afforded, here we find the socially conscious engineer, trained in subjects shaped by local conditions, responsible for the good of both society and the state. Technology in Prussia was thus bound to social values, albeit in a different way than in France.⁸⁷

An outlook generated by geopolitics had a domestic politics of its own. There was a catch to constructing their identity in this way. Prussian engineers could secure roles as protectors of the public good, the general welfare, and the state's interests only to the degree that their projects worked. From one perspective their incessant invocation of the proper way to integrate theory and practice merely expressed the dilemma of engineers throughout the century: how to achieve a balance between the two that was meaningful and productive. Prussian discussions were not so simple. In 1796, while pressing Prussia's government for an institution where architects and engineers could be instructed, they found it fitting to republish an essay by the military engineer Humbert, who had instructed Frederick II, because he argued so strongly for such instruction. Reflecting the prejudices of his age, Hum-

84. Johann Samuel Lilienthal, «Beschreibung des Memelschen Hafens, und der in den letzten 50 Jahren bey solchem vorgenommenen, und noch vorzunehmenden Vermessungen, nach Maassgabe des beygefügtten Plans», *SNA* 3.2 (1799): 53-73, on 72.

85. Riedel, «Fortsetzung», *SNA* 1.2 (1797): 7.

86. Antoine Picon, *French Architects and Engineers in the Age of Enlightenment* (Cambridge: Cambridge University Press, 1992), 110.

87. Ken Alder, «French Engineers Become Professionals or, How Meritocracy Made Knowledge Objective», in *The Sciences in Enlightened Europe*, ed. William Clark, Jan Golinski, and Simon Schaffer (Chicago: University of Chicago Press, 1999), 94-125.

bert remarked that architects and engineers without training in the sciences, especially mathematics, were «architectonic Jews» who merely «blabbered».⁸⁸ His invocation of Prussian society's «outsiders» in this way underscores the degree to which those with technical expertise were increasingly viewing themselves as «insiders» now entrusted with public duties that surpassed their core role as builders of the state's physical infrastructure to include a commitment and an obligation to improve society. When Eytelwein was elected a member of the Berlin Academy of Sciences, an august body of mostly theoreticians of knowledge, he argued in his entrance speech that it was insufficient merely «to expand the limits of knowledge»; one also had to make knowledge useful «for public welfare». «Many branches of knowledge», he continued,

are not yet suited to grasp their usefulness for civil society (*bürgerliche Gesellschaft*) and still less to be recognized by a considerable part of civil society as useful for public welfare. It would, of course, be detrimental for the sciences if their culture were made dependent merely on the measure of their direct use. But it's also not to be denied that many subjects are capable of finding a broader treatment and application for the good of the state. No patriot can suppress the wish that the gap that still exists between those who cultivate the sciences and those who have undertaken to have an effect directly on the state —I mean, the difference between theory (*Theorie*) and practice (*Praxis*)— will no longer be as large as it is now.

Those engaged in practical pursuits, he observed, «are in dire need of a broader acquaintance with the sciences», while those «who possess a great talent for the expansion of human knowledge seldom know broadly of the needs of civil life». From his colleagues at the Academy he hoped «to learn how it is best feasible to be as useful for public welfare as circumstances allow, and certainly the approval of our most sincere honored monarch, the promoter of everything useful and good, will crown such works».⁸⁹ In his response to the address, Johann Bernhard Merian, the perpetual secretary of the Academy, notably singled out hydraulic engineering as the main area where geometry had been taken out of «the realm of the sublime» and put in service of the public good and the Prussian state.⁹⁰ And yet their notion of «public good» —the ethical bridge they constructed between theory and practice— here was fraught with its own prejudices: the superiority of Prussians over Poles,

88. Abraham von Humbert, «Ueber den guten Geschmack in der Baukunst», *Allgemeines Magazin für die bürgerliche Baukunst* 2 (1796): 147-189, on 150.

89. Johann Albert Eytelwein, «Antrittsrede», *Sammlung der deutschen Abhandlungen, welche in der Königlichen Akademie der Wissenschaften zu Berlin vorgelesen worden in den Jahren 1803*, 2-3.

90. Johann Bernhard Merian, «Response au Discours a Réception de Monsieur Eytelwein», *Mémoires de l'Académie Royale des Sciences et Belles-Lettres* 1803, 46.

and of civilization over wilderness. In so many respects, then, the distinction between knowledge and society eluded them. After all, Prussian surveying and hydraulic engineering experiences were acquired largely under conditions linked to particular social concerns: the marginalization of Jews, the backwardness of Slavs and Poles, and the identification of Slavic and Polish Prussian lands with wilderness. The geopolitical circumstances within which Prussian technical instruction emerged thus shaped the ethos of the engineer as much as it did the technical practices of hydraulic engineering.