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Ruder Bošković's Expert Analyses in Hydraulic Engineering

An Unexamined Dimension of Bošković's Work

Ruder Bošković's professional expertise in hydraulic engineering is the least studied dimension of his work, despite the fact that it has always been noted in his biographies, from Bernard Zamagna's funeral oration and Francesco Ricca's eulogy to Elisabeth Hill's biographical essay and Željko Marković's monograph.¹ His proposal for the drainage of the Pontine Marshes has always received due attention. However, only in Ricca's bibliography of Bošković's works (Ricca was Bošković's friend from his student days at the Collegium Romanum), were the studies in hydraulic engineering listed under the separate heading of *Opere d'Idrodinamica*.² Ricca classified them according to subject, not in chronological order, distinguishing between three fields of Bošković's interest in hydraulic engineering:

- (1) rivers, water supply and fountains
- (2) ports
- (3) marshes.

He concluded this section of Bošković's bibliography in 1789 with the following remark: "All or almost all of these papers have been published, but in some cases I have not been able to establish the location."³ Ricca seems

1 Cf. Bernardus ZAMAGNA, *Oratio in funere Rogerii Josephi Boscovichii habita XII Kal. Junii* (Rhadusii: Ex Tipogr. Privileg., 1787), pp. 8-9; Francesco RICCA, *Elogio storico dell'Abate Ruggiero Giuseppe Boscovich* (Milano: Nella Stamperia di Giuseppe Marelli, 1789), pp. 32, 70-72; Elisabeth HILL, "Roger Boscovich: A Biographical Essay," in Lancelot Law WHYTE (ed.), *Roger Joseph Boscovich S.J., F.R.S., 1711-1787: Studies of his life and work on the 250th anniversary of his birth* (London: George Allen & Unwin Ltd., 1961), pp. 79-80; Željko MARKOVIĆ, *Rude Bošković*, vol. 1 (Zagreb: JAZU, 1968), pp. 316-317.

2 "Indice delle opere dell'Ab. Ruggiero Giuseppe Boscovich pubblicate prima della sua morte," in RICCA, *Elogio storico*, pp. 108-116, on pp. 110-111.

3 RICCA, *Elogio storico*, p. 111: "Tutte, o quasi tutte queste Scritture sono stampate, ma non si è potuto sempre accertare il luogo."

to have created confusion where one would have expected him to be well informed. For example, the following works by Bošković were not published during his life, although preserved in manuscript: his assessment of the damage to the timber piles in the Fiumicino in 1750–1751, his several reports from 1756 on the marshes near Lago di Sesto where the River Arno had flooded the border area between the Republic of Lucca and the Duchy of Tuscany, and his expert opinion on the fountains in Perugia from 1772.

A Chronological List of Bošković's Expertise in Hydraulic Engineering

Faced with inconclusive basic data related to Bošković's projects in hydraulic engineering, I first tried to establish the exact date of their origin and classify them chronologically. My search through the libraries of Dubrovnik and Rome has resulted in the following list, which was also supplemented and confirmed by a comparative study of Bošković's bibliographies, Branimir Truhelka's 1924 catalogue of Bošković's manuscript legacy currently kept in the Bancroft Library in Berkeley (CA, USA) and Bošković's correspondence. Although incomplete, the list is truly impressive, being limited only to manuscripts and editions with complete bibliographical data, including the date of origin and publication as follows:

- (1) assessment of damage to the timber jetties in the Fiumicino, the navigable branch of the River Tiber (1751);
- (2) the Ozzeri project, spurred by a bitter controversy on the floods in the border area between Lucca and Tuscany (1756);
- (3) plan for the drainage of the Pontine Marshes, including the evaluation of an earlier project by Manfredi and Bertaglia (1764);
- (4) analysis of the causes of damage to the port of Rimini, accompanied by reparation measures (1764);
- (5) assessment of the levees along the River Po (1764);
- (6) scientific letter on the principles of hydrodynamics in Lecchi's *Idrostatica* (1765);
- (7) report on the floods in the Perugia area (1766);
- (8) official report on the damage to the port of Savona, the underlying causes and the possibilities of repair (1771);
- (9) expert opinion referring to the River Tidone in the Piacenza area (1771);

- (10) proposal for the renovation of the fountains in Perugia (1772);
- (11) expert opinion on the mouth of the River Adige as compared with the proposals by Antonio Lorgna and Šimun Stratik for the improvement of the river bed (1773);
- (12) instructions for the establishment of a team responsible for the drainage of the Pontine Marshes (1774);
- (13) comments on Ximenes's project for the Nuovo Ozzeri drainage channel in Lucca (1781).⁴

A glance at the above list will reveal that Bošković was involved with the problems of hydraulic engineering for a considerable number of years, 1751 to 1781, especially between 1764 and 1773, from his definite departure from Rome to his professorship of mathematics in Pavia and Milan. His proposal for the drainage of the Pontine Marshes, made at the beginning of this fruitful period, was not the only one, nor was it accepted immediately. Others had also suggested projects before Bošković, including Romualdo Bertaglia (1729), Eustachio Manfredi, Msgr. Bolognini and the geodesist Angelo Sani (1759), while Gabriele Manfredi and Romualdo Bertaglia had presented a joint proposal (1761). Leonardo Ximenes visited the Pontine Marshes on the same task only a year later than Bošković (see Figure 1).⁵

Bošković's plan for the drainage of the Pontine Marshes and the reconstruction of the port of Terracina seems to have become the focus in his biographies, probably because he risked catching an infectious disease, the solution of an ancient controversy was at stake and the project had been commissioned by such eminent persons. In his letter of 23 January 1764 to Giovan Stefano Conti, Bošković critically analyzed his own plan for the Pontine Marshes.⁶ The letter contains many details concerning the circumstances in which Bošković had to judge the project proposed by Manfredi and Bertaglia. He was then engaged in a study of optical phenomena and was also preparing for a journey to Pavia, where he was expected to receive the Chair of Mathematics at the Collegium Ticinense and restore it to its former

⁴ See complete bibliographical data in the appendix "A Catalogue of Bošković's Manuscripts and Published Works on Hydraulic Engineering and Hydrodynamics."

⁵ Cf. Leonardo XIMENES, "Notizie Istoriche ..., intorno alla Relazione de' due Professori Gabriele Manfredi, e Romualdo Bertaglia su disseccamento delle Paduli Pontine," in *Raccolta delle perizie ed opuscoli idraulici del Signor Abate Leonardo Ximenes ... alla quale si aggiungono le perizie di altri Professori che anno scritto sulle stesse materie*, Tomo I. (Firenze: Nella Stamperia di Pietro Allegrini, 1785), pp. 1-6.

⁶ Ruđer Bošković to Giovan Stefano Conti, 23 January 1764, in Ruggiero Giuseppe Boscovich, *Lettere a Giovan Stefano Conti*, a cura di Gino Arrighi (Firenze: Leo S. Olschki, 1980), pp. 113-114.

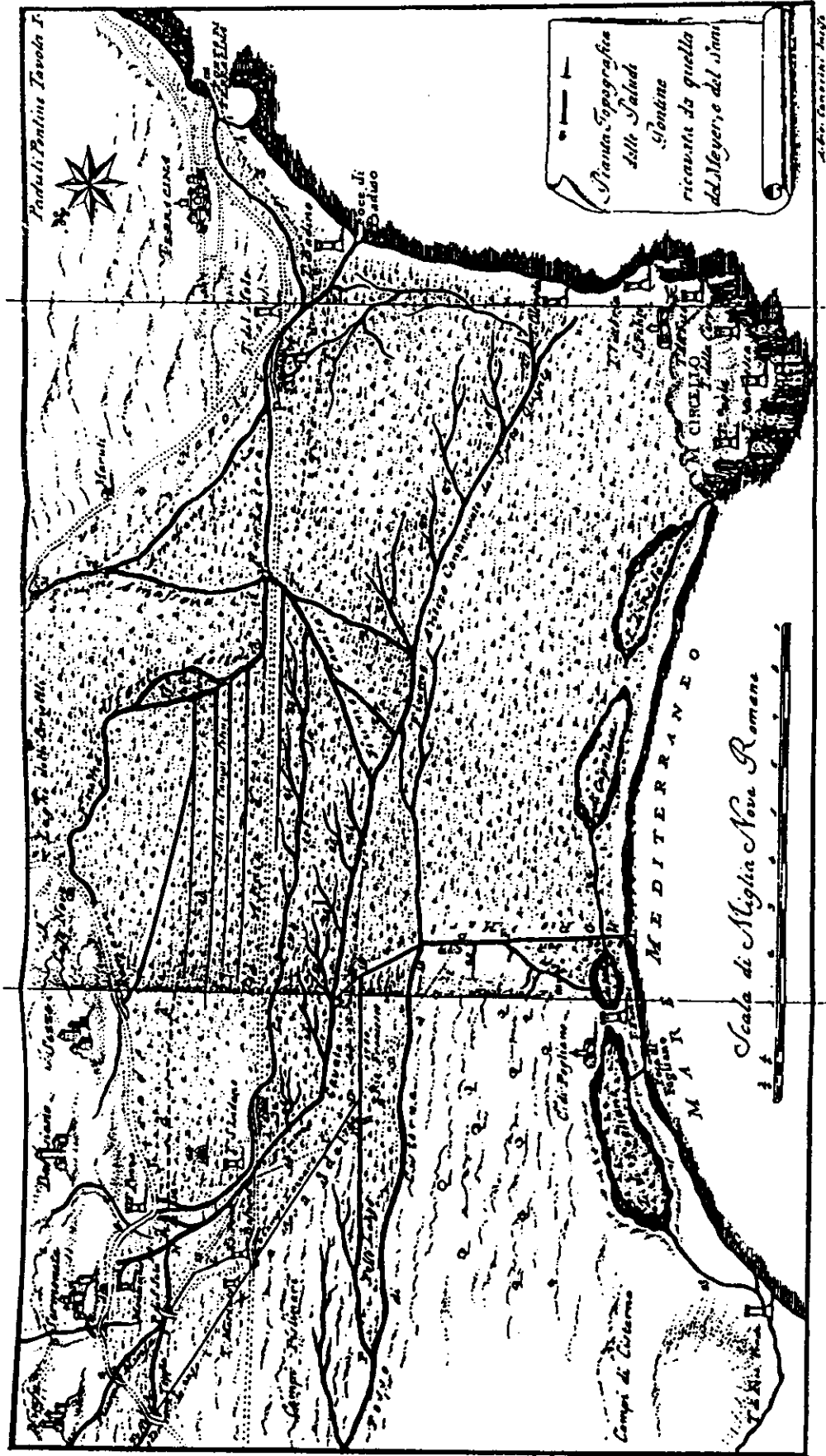


Figure 1. A topographical map of the Pontine Marshes from Ximenes's collection of evaluations and works on hydraulic engineering, *Pianta Topografica delle Paludi Pontine*, in Ximenes, *Raccolta delle perizie ed opuscoli idraulici*, Tomo I. (Firenze: Allegrini, 1785).

glory. He did not even have the basic instruments with him, which means that he was not prepared to survey an area of about 60,000 hectares and make an evaluation. It was not his habit to approach such a task unprepared, as evident by his systematic preparations made for measuring the degrees of the meridian between Rome and Rimini, which took several months. Nevertheless, he had to do his best under the circumstances. Despite all the difficulties, he remained in the dangerous swamps for "a short period" of ten weeks.

A detailed description of the historical circumstances and a scientific study of each of the evaluations on the above-mentioned list represent more than sufficient material for yet another article. My aim in the present study is to expose the main features of Bošković's contribution to hydraulic engineering and hydrodynamics. On the social level, Bošković exhibited ongoing concern for improvement in the teaching of applied mathematics, including the promotion of achievements in hydrodynamics and hydraulic engineering, as well as competition or cooperation with Jesuit professors of mathematics at other Italian universities, also experts in hydraulic engineering. Viewed from the scholarly perspective, Bošković's approach is best reflected in the choice of the methods he applied to formulate his proposals.

Within the Educational System

Bošković's interest in hydraulic engineering can be traced back to his first lectures on mathematics at the Collegium Romanum. In his letter of 13 September 1740 to Marquis Zambecari, the father of one of his students, Bošković clearly stated his intentions and the contents of his lectures. He expected that one day some of his students would become prelates at the Papal Court and be in position to decide on various matters concerning the construction and maintenance of waterways and, above all, the expenditures for such projects.⁷ In his opinion, only those who knew the principles of geometry and mechanics well would be able to make the proper decisions.

7 Ruđer Bošković to the father of the Marquis Giacomo Zambecari, 13 September 1740, published in Vladimir VARIČAK (ed.), "Ulomak Boškovićeve korespondencije," *Rad JAZU*, 185 (1911), pp. 243-453, on p. 274: "ma in modo particolare pensavo alla vita che menano i Prelati di questa Corte, una gran parte de'quali si trova all'impegno di giudicare in varie materie o di spese da farsi nelle fabbriche, o di direzione d'acque, che non possono in conto alcuno intendersi senza i principj della Geometria, e della Mecanica."

In 1754, in the preface to the third volume of his textbook on mathematics *Elementa universae matheseos*, Bošković expressed his intention to devote a considerable part of the fourth volume to applied mathematics. *Mathesis mixta* was to include the following disciplines: mechanics, optics, gnomonics, astronomy, geography, chronology, civil and military engineering, and music.⁸ Such or similar knowledge of applied mathematics could be found in other contemporary textbooks on mathematics, e.g., in the introduction to La Caille's textbook, in which a table is included showing the division of mathematics into different branches.⁹ If Bošković regarded mechanics as a part of applied mathematics, he also considered hydrodynamics, dealing with the mechanics of fluids, and hydraulics, dealing with the mechanics of water, to be a part of applied mathematics.

Although Bošković announced the fourth volume of his mathematics textbook several times, he never wrote it, one reason probably being his departure from the Collegium Romanum in 1756. His appointment as a professor of mathematics at the University of Pavia revived Bošković's ideas about the teaching of mathematics being appropriate for the training and refinement of the mind and, at the same time, useful in the civil service. He was supported in this by the Senate of Milan, which in its decree dated 22 November 1763 stated that "great rulers had also utilized his keen mind, his great erudition, and his experience when difficult and costly projects were to be undertaken."¹⁰ In his *Piano scientifico*, Bošković expounded his views on the teaching of mathematics and physics, suggesting that there should be two professors of mathematics: one for elementary mathematics and the other for advanced mathematics. "In the second year of teaching," the latter "would lecture on mechanics and its borderline problems, with emphasis on all the theory and practice of water ..."¹¹ The students who wanted "to study those

8 "Auctoris praefatio," in Rogerius Josephus BOSCOVICH, *Elementorum universae matheseos ... tomus III*. (Romae: Salomoni, 1754), pp. [1]-[2] (without pagination), on p. [2]: "Hinc absolutis, quae ad puram Mathesim pertinent, aggrediar mixtam. Primo quidem ea, quae ad motum pertinent, tum quae ad Lucem, exponam, deinde Sphaeram, & ex ea pendentem Gnomonicam, tum Astronomiam praecedentibus omnibus indigentem evolvam, quibus adiiciam demum illa, quae ex Mathesi requiruntur ad Geographiam, Chronologiam, utramque Architecturam, & Musicam, si nimirum vita, & otium supererit."

9 "Idea generale delle Matematiche," in *Elementi di Matematiche pure secondo il metodo del Chiarissimo Signor Abbate de La Caille*, Edizione seconda Italiana accresciuta del Trattato della Trigonometria Sferica del Padre Ruggiero sic! Giuseppe Boscovich (Venezia: Presso Tommaso Bettinelli, 1775), pp. 1-6, particularly "Tavola di tutta la divisione delle Matematiche," p. 5.

10 See the diploma "Ad Ven. P. Rogherius Boscovik [sic!] ex Societate Jesu Matheseos Professore electum in Reg. Ticinensi Universitate," published in Vladimir VARIČAK, "Prilozi za biografiju Rudža Boškovića," *Rad JAZU*, 234 (1928), pp. 123-188, on pp. 169-170.

11 *Piano scientifico del P. Ruggiero Giuseppe Boscovich della Compagnia di Gesù*, the autograph in the Archivio di Stato, Milano, ff. 1-2, in the section "Per le Matematiche," f. 1v: "In un altr'

branches of mathematics which, like navigation, were neglected because there was little demand for them in this country" would be taught in tutorials.¹²

Bošković expressed the same views in *De Libris, qui desiderantur pro classe Mathematica Universitatis Ticinensis* [On Books Required for the Department of Mathematics at the University of Pavia], where he drew attention to the fact that in Pavia "there is no public or private library that has at least a modest choice of mathematical books."¹³ He therefore made a list of the most important books to be purchased for the University library, leaving out those he possessed himself and the ones that could be found at the Jesuit College. In addition to many books written by 17th and 18th century scientists on astronomy and mathematics, the list contained several contemporary works on navigation and hydraulics, the titles of which he wrote from memory, mostly in Latin and sometimes in French, although not always correctly, as follows:

- (1) three works on navigation by Pierre Bouguer (1698–1758), *Construction des Vaissaux*, *Pilotage* and *Manevre*, most likely referring to Bouguer's *Nouveau traité de navigation, contenant la théorie et la pratique du pilotage* (Paris, 1753);
- (2) *Astronomie nautique* (Paris, 1743) by Pierre Louis Moreau de Maupertuis (1698–1759);
- (3) *Architectura hydraulica* (Paris, 1737–1751) by Bernard Forrest de Belidor (1697–1761) in four volumes.¹⁴

anno darà la Mecanica colle sue adiacenze, insistendo soprattutto su tutta la teoria, e pratica delle acque ..." About this manuscript, see: VARIČAK, "Prilozi za biografiju Rudža Boškovića," p. 126; Željko MARKOVIĆ, *Ruđe Bošković*, vol. 2 (Zagreb: JAZU, 1969), p. 648.

12 *Piano scientifico del P. Ruggiero Giuseppe Boscovich della Compagnia di Gesù*, also in the section "Per le Matematiche," f. 1v: "Esso Lettore diriggerà ne' loro privati studj quelli, che ... verranno ... studiare quelle parti di Matematica, che pel minor uso loro in questi paesi, si tralasciano, come la Nautica."

13 Rogerius Josephus BOSCOVICH, *De Libris, qui desiderantur pro classe Mathematica Universitatis Ticinensis*, the autograph in the Archivio di Stato, Milano, ff. 1–2, na f. 1r: "... in ea urbe, in qua nulla adest Bibliotheca publica, nulla privata vel mediocriter instructa libris Mathematicis."

14 See the reference on these editions in BOSCOVICH, *De libris, qui desiderantur pro classe Mathematica Universitatis Ticinensis*, f. 1r: "Bouguerii de mensura graduum, et figura Telluris. Ejusdem tri opera Nautica *Construction des Vaisaux* (sic!), *Pilotage*, *Manevre* Maupertuisii opera plura: De Figura Terrae determinata, de Figura Astrorum, Astronomia Nautica. Belidori opera, potissimum *Architectura Idraulica*." About this manuscript of Bošković, see MARKOVIĆ, *Ruđe Bošković*, vol. 2, p. 656.

He was later to add a collection of papers on hydraulics in seven volumes, which had just been published in Parma. He explicitly stated that he himself had a copy of *Hydrodinamica* (Strasbourg, 1738) by Daniel Bernoulli (1700–1782).

Rivals and Collaborators among the Jesuits

Regarding expertise in hydraulic engineering and the promotion of the teaching of hydrodynamics, Ruđer Bošković was no exception among the professors of mathematics and astronomy at the Italian Jesuit colleges at the time. The number of Jesuit professors, rivals and collaborators that Bošković met throughout many years of involvement with hydraulic engineering is quite impressive. His greatest rival was Leonardo Ximenes (1716–1786), a professor of geography and mathematics, the founder of the St. Giovannino Observatory in Florence, and the author of numerous professional reports, including several on the regulation of river flows in the regions of Bologna, Ferrara and Romagna, and on the bed of the River Po.¹⁵ Bošković defended the interests of Lucca in the controversy between Lucca and Tuscany (1756–1758), while Ximenes supported Tuscany. The two experts engaged in separate professional negotiations at Ripafratta.¹⁶ At the court of Empress Maria Theresia, Bošković won the case. The Senate of the Republic of Lucca conferred a noble title upon him on 16 September 1757 “for having fulfilled the task entrusted in such a learned, skillful and praiseworthy manner.”¹⁷

That was not the end of the scholarly competition between Ruđer Bošković and Leonardo Ximenes. A year after Bošković’s visit, in March and April 1765, Ximenes visited the Pontine Marshes and wrote several reports with proposals for the reclamation of the land and critical comments on

15 See “Indice delle relazioni, che trattano de’Fiumi Bolognesi,” in *Raccolta delle perizie ed opuscoli idraulici del Signor Abate Leonardo Ximenes ... alla quale si aggiungono le perizie di altri Professori che anno scritto sulle stesse materie*, Tomo I., p. XX.

16 Cf. Ruggiero Giuseppe BOSCOVICH, *Conferenza privata col P. Ximenes degli 11 Settembre 1756 in Ripafratta, e varie riflessioni sulle correnti vertenze*, the manuscript kept in the Archivio di Stato, Lucca, *Offizio sopra i Paludi di Sesto*, 51.

17 See the certificate of nobility issued on 18 September 1757, and kept in the Archivio di Stato, Lucca, *Anziani al tempo della libertà*, 422, f. 103, and published in Gino ARRIGHI, “Ruggiero Giuseppe Boscovich e Lucca,” *Actes du Symposium international R. J. Bošković 1961* (Beograd / Zagreb / Ljubljana: Conseil des Academies RFPY, 1962), pp. 269–281, on p. 269: “Et cum ipse [Rogerius Joseph Boscovich de Ragusia] suscepti muneri partes tam doctè, egregiè, ac laudabiliter expleverit ...”

earlier plans, including the one by Ruđer Bošković.¹⁸ Their roles were reversed later. In an extensive paper dated 25 September 1778, Ximenes proposed the construction of a new drainage channel called Nuovo Ozzeri that would drain water from Lago di Sesto in the border area between Lucca and Tuscany, take it across the territory of Lucca and below the bed of the River Serchio all the way to Lago di Maciuccoli; this water would then flow through the existing network of channels towards the port of Viareggio (see Figure 2). At the request of Lucca, Bošković agreed to write an evaluation of Ximenes' plan. Although he was in Paris in 1781 and a long way from the location, he and Ximenes exchanged views. Ximenes then wrote another paper trying to refute Bošković's arguments. The editor, who would not reveal his name, but can reasonably be assumed to be Bošković's correspondent Giovanni Attilio Arnolfini, published all three documents in 1782 — Ximenes's project, Bošković's review and Ximenes's reply — in a special edition containing the plans for the hydraulic works in Lucca.¹⁹ The debates between Bošković and Ximenes, which continued from 1756 to 1781 and were supported by well-documented arguments on both sides, did not mar the reputation of either of them. Moreover, while the discussion about the Nuovo Ozzeri drainage channel was at its height, the two men, one from Dubrovnik and other from Sicily, accepted the offer of Antonio Lorgna to be among the first forty members of the natural academy *Società Italiana*, nowadays *Accademia dei Quaranta*, which was founded by Lorgna in Verona in 1782.²⁰

Bošković's cooperation with the Jesuit Lecchi, the author of *Idrostatica esaminata ne' suoi principj*, contrasted with this competitive relationship. Antonio Lecchi (1702–1776), responsible for the hydraulic works in the time of Pope Clement XIII and professor at the University of Pavia, asked Bošković to write a special contribution to his monograph on the principles of hydrostatics. Bošković then wrote a scientific letter “on the principles upon

18 See, for example, “Prima Relazione, e Perizia delle bonificazione superiore delle Paludi Pontine, regolata secondo le nuove osservazioni fatte nella Visita del mese di Marzo, ed Aprile 1765,” in Ximenes, *Raccolta delle perizie ed opuscoli idraulici*, pp. 125–230.

19 *Piano di Operazioni Idrauliche per ottenere la massima depressione del Lago di Sesto o sia di Bientina* (Lucca: Presso Francesco Bonsignori, 1782) included the following papers: “Relazione generale del Signore Abate Leonardo Ximenes,” pp. 1–172; “Riflessioni sulla Relazione del Sig. Abate Ximenes appartenente al Progetto di un Nuovo Ozzeri nello Stato Lucchese del Signore Abate Ruggiero Giuseppe Boscovich,” pp. 173–205; “Informazione del Signore Abate Leonardo Ximenes intorno alle Riflessioni del Sig. Abate Boscovich, ed intorno all'Esame del Sig. Eustachio Zanotti sulla sua Relazione Generale de' 25. Settembre 1778 appartenente al Progetto di un Nuovo Ozzeri nello Stato della Repubblica di Lucca,” pp. 241–347. The third paper also contained “Parte prima dell'Informazione relativa alle Riflessioni del Sig. Abate Boscovich,” pp. 245–280.

20 Cf. “Elenco cronologico dei soci nazionali,” in *Annuario* (Roma: Accademia Nazionale delle Scienze detta dei XL, 1990), pp. 48–58, on p. 48.

which practical rules are based that serve to measure the water issuing from apertures and flowing in river beds,”²¹ and Lecchi, as editor, included it as the leading article in the third part of his monograph. Since Bošković was well-acquainted with Lecchi’s text, he began his letter with the following words: “I shall consider the subject in relation to what you have established so well in the first two parts of the book you are preparing for publication.”²² Bošković was a very demanding reviewer of Lecchi’s book. The nature of their cooperation is probably best displayed in a letter of 15 October 1780 to Francesco Puccinelli, in which Bošković wrote that he had worked hard on Lecchi’s *Idrostatica*, correcting a badly written passage and rewriting the first two parts completely with many important appendices.²³

The Jesuits who were engaged in the problems of hydraulic engineering kept in touch after the suppression of the Society of Jesus in 1773, and some of them acquired permanent positions through these connections. Their relationship is best understood from Bošković’s letter of 8 January 1774 to Puccinelli, who had been his valuable assistant at the Brera observatory in Milan, the post he was removed from by order of the Viennese Court in August 1772, on account of his fruitful collaboration with Bošković. Puccinelli subsequently became an assistant to Leonardo Ximenes in a project to drain marshland in Tuscany. In the above-mentioned letter, Bošković encouraged his former student to devote himself to hydraulic expertise, to pursue Ximenes’ instructions and in order to achieve greater insight into hydraulic engineering, he was to consult, together with other works, Lecchi’s *Idrostatica*.²⁴

21 See the title of Bošković’s contribution: “Lettera del P. Boscovich sulli principj, su’ quali si possano appoggiare le Regole pratiche per la misura dell’ acque, ch’ escono dalle aperture, e corrono per gli alvei,” in Antonio LECCHI, *Idrostatica esaminata ne’ suoi principj e stabilita nelle sue regole della misura dell’ acque correnti* (Milano: Nella Stamperia di Giuseppe Marelli, 1765), pp. 319–345, on p. 319.

22 “Lettera del P. Boscovich ...,” p. 319: “... e tratterò la materia correlativamente a quanto Ella ha stabilito molto bene nelle prime due Parti dell’Opera, che prepara per le stampe.”

23 Ruder Bošković to Francesco Puccinelli, Pont-sur-Seine, 15 October 1780, in Ruggiero Giuseppe BOSCOVICH, *Lettere per una storia della scienza (1763–1786)*, a cura di Rita Tolomeo (Roma: Accademia Nazionale delle Scienze detta dei XL, 1991), pp. 152–154, on p. 153: “... solo non mi sarei aspettato un tradimento dal Lecchi, che mi era tanto obbligato per quello, avevo fatto con tanta mia fatica per la sua *Idrostatica*, liberandolo dal cattivo passo, correggendo tanti errori, e rifacendo con tante aggiunte essenziali totalmente le due prime parti: ma il suo carattere era finto, e doppio.” Cf. Željko MARKOVIĆ, *Ruđe Bošković*, vol. 2, p. 897.

24 Ruder Bošković to Francesco Puccinelli, Paris, 8 January 1774, in BOSCOVICH, *Lettere per una storia della scienza (1763–1786)*, pp. 92–93, on p. 93. Cf. MARKOVIĆ, *Ruđe Bošković*, vol. 2, p. 822.

Measurements and Theoretical Explanations

Bošković published only two works on hydraulic engineering and hydromechanics in his lifetime: an expert analysis of damage to the port of Rimini and a letter about the principles of hydrodynamics in Lecchi's *Idrostatica*.²⁵ Both were published with Bošković's consent and exemplify the methodology he used in his professional reports in hydraulic engineering and hydrodynamics. Furthermore, these two papers are completely different in character. The first paper is an example of a well-written expert study of a harbor, while the other is a theoretical essay on the determination of the average velocity of a flow. Therefore, analysis of Bošković's methods in these two papers provides insight into his scientific methodology.

Bošković's report on the port of Rimini was the result of his systematic investigation of the phenomena in the port and along the nearby coast in October 1764. On the one hand, the request of the councilors of Rimini obliged Bošković to adopt an experimental approach, since they wanted him to come as soon as possible and give them his "opinion regarding the future management of the port based on the state easily established by the naked eye."²⁶ On the other hand, by the time he was asked to go to Rimini, Bošković had acquired great practice in providing port expertise. The port of Rimini was the fourth port on which he gave an expert evaluation, preceded by strenuous field work. In February 1751, while he was measuring two degrees of the meridian between Rome and Rimini, accompanied by Christopher Maire, he wrote his first analysis, the one about the Fiumicino, the navigable branch of the Tiber, and the old port called Porte di Trajano. In his historical and physical commentary on the journey through the Papal State, Bošković noted that he gladly visited the mouth of the Tiber after the great flood of December 1750. One of the reasons was to estimate the damage and propose protective measures against possible floods, and the other, equally important for Bošković and in accordance with his scientific pursuits, was "to chart the border locations, both mouths of the Tiber, the coastline

25 See Ruggiero Giuseppe BOSCOVICH, *Del Porto di Rimini memorie* (Pesaro: Presso Donnino Ricci, 1765), 71 pp; "Lettera del P. Boscovich sulli principj, su' quali si possano appoggiare le Regole pratiche per la misura dell' acque, ch' escono dalle aperture, e corrono per gli alvei," in Antonio LECCHI, *Idrostatica esaminata ne' suoi principj e stabilita nelle sue regole della misura dell' acque correnti* (Milano: Nella Stamperia di Giuseppe Marelli, 1765), pp. 319–345.

26 Ruggiero Giuseppe BOSCOVICH, *Del Porto di Rimini memorie*, in "Proemio," pp. 1–3, on p. 1: "... *sul futuro contegno nella direzione del loro Porto il mio sentimento fondato sull' evidenza di quelle prove, alle quali potesse dare tutto il comodo l'oculare ispezione.*" Italicized by Bošković.

and the location of coastal fortifications.”²⁷ The result was Maire’s map of the Papal State (1755) based on the observations of Bošković and Maire, on which the Tyrrhenian coast of the Papal State was drawn with great accuracy.

One year before he received the request of the councilors of Rimini, more precisely in the period between 18 January and 2 April 1764, Bošković was in the Pontine Marshes, and by 6 April at the latest, at an official audience in the Apostolic Palace, he had presented a fair copy of his report containing his opinion on the project of Manfredi and Bertaglia.²⁸ The report also included his opinion about the port of Terracina on the south edge of the Pontine Marshes, where the Amaseno tributary deposited large quantities of silt (see Figure 3).²⁹ In some of his proposals, Bošković made reference to his first port evaluation and the experience he gained from it. He suggested setting up two timber jetties that would enable felluccas to enter the port, as he further advocated for the preservation of the old port.

Before going to Rimini, Bošković visited the port of Magnavacca, as can be seen from his report on the port of Rimini, in which he mentioned his involvement in the problem of the navigable branch of the Tiber and the port of Terracina and his experience from Magnavacca.³⁰ Truhelka’s catalogue of Bošković’s manuscript legacy includes the bibliographical item of a report “on the damages and the repairs” (*sui danni, e rimedj*) in the port of Magnavacca, which I did not include either in the chronology of Bošković’s works in hydraulic engineering or in the list in the Appendix, as I could not establish the exact date of the origin of Bošković’s expertise.³¹ Bošković, who was by that time well-versed in port expertise, started work as soon as he arrived in Rimini, on 5 October 1764, applying the methodology he had perfected in the

27 Rogerius Josephus Boscovich, “Litterariae per Pontificiam ditionem expeditionis Commentarius historicus, ac physicus,” opusculum I. in: Christophorus MAIRE et Rogerius Josephus BOSCOVICH, *De litteraria expeditione per Pontificiam ditionem ad dimetiendos duos meridiani gradus et corrigendam mappam geographicam* (Romae: Nicolaus, et Marcus Palearini, 1755), n. 102, p. 54: “... ut finitima loca, & utrumque Tyberis ostium, ac oram littoris, & turrium maritimarum situs definiremus.”

28 Ruđer Bošković to Giovan Stefano Conti, Firenze, 12 April 1764, in Ruggiero Giuseppe BOSCOVICH, *Lettere a Giovan Stefano Conti*, pp. 132–133, on p. 132.

29 Cf. “Esame del Progetto de’Sigg. Manfredi, e Bertaglia in riguardo alle Paludi Pontine, e Porto di Terracina del Sig. Abate Ruggiero Giuseppe Boscovich, allora Professore di Matematica nell’Università di Roma de’PP. Gesuiti,” in Leonardo XIMENES, *Raccolta delle perizie ed opuscoli idraulici ... alla quale si aggiungono le perizie di altri Professori che anno scritto sulle stesse materie*, Tomo I. (Firenze: Nella Stamperia di Pietro Allegrini alla Croce Rossa, 1785), pp. 75–115, particularly the chapter “Del Porto di Terracina,” pp. 104–108.

30 BOSCOVICH, *Del Porto di Rimini memorie*, pp. 44, 66.

31 *Relazione della visita fatta al Porto di Magnavacca dal P. Ruggiero Giuseppe Boscovich della Compagnia di Gesù e suo sentimento sui danni, e rimedj*, Ms. 46 in Branimir TRUHELKA, “Katalog rukopisa,” in *Grada za poznavanje života i rada R. Boškovića: Katalozi*, fasc. XV, f. 101.

vista il provvedimento, che ho ivi suggerito, per rinfrescare l'acqua del Fiume d'Olevola, che rimarrà una specie di Lago, quando ciò si riconosca necessario, per impedire la corruzione.

P A R T E III.

Del Porto di Terracina.

PER formare un Porto in Terracina, prescrivono, che l'Amaseno si devii dal suo corso presente in un punto, che rimane da quattro miglia più sù della Tenuta de' Signori Gavotti, e si porti diagonalmente per i Campi di Sonnino, in un punto, in cui arriva alla Tenuta medesima il Fosso de' Maruti, poco più giù della Pórtata di tal nome, e vi trova un'Alveo, che si chiama il Fiume vecchio della *Pedicata*, costeggiando il piè de' Monti. Per quest'Alveo bene escavato, e arginato lo portano a passare la Via Appia sotto alcuno de' Ponti, che vi sono, e aggiungono esser credibile, che l'Amaseno sia già ito altre volte per quella via. Intanto fanno, che l'Usente passi la Via Appia sotto il Ponte maggiore, ove là passava sicuramente una volta vicino al sito delle Macerie, ove ora là passa unito già all'Amaseno. Lo fanno tirare innanzi lungo la Via Appia, finchè trovi l'Amaseno vicino alla Torre delle Mole; indi uniti gli portano al sito dell'antico Porto interrto, ove si fanno sboccare in mare alla punta del Molo. Prescrivono la forma dell'Alveo, e degli Argini. Aggiungono due altri Archi al Ponte di pietra, che vi è sotto la Città sul Fiumicello. Formano due lunghi muri da esso Ponte fino allo sbocco colle colonnette, per legarvi le Navi, e fanno un Molo nuovo alla punta del vecchio, per difendere l'imboccatura.

Dicono, che questo sarà un Porto a Canale migliore assai di quello di Sinigaglia, e che per altro gioverà anche per migliorare la bonificazione, perchè così l'Usente entrando

Figure 3. The beginning of the chapter on the port of Terracina. Boscovich, "Esame del Progetto de'Sigg. Manfredi, e Bertaglia in riguardo alle Paludi Pontine, e Porto di Terracina," in Ximenes, *Raccolta delle perizie ed opuscoli idraulici*, Tomo I. (Firenze: Allegrini, 1785), pp. 75-115, on p. 104.

meantime (see Figure 4). The self-consciousness of an expert is reflected in his description of this methodology in the introduction to the report.³² Bošković's approach was based on careful daily measurements of the depth in the port and the observation of the currents and regular effects of the sea. "I have spent all morning measuring the depths in the port," Bošković wrote to Conti on 13 October 1764.³³ On two occasions during his stay, the tide remained very high (*grossa piena*) for two days, with storms coming from the east and the northeast. Bošković could see for himself the damage to the right wharf caused by the first storm, the worse one, which made the entrance to the port even more difficult. He not only measured the depth and observed the phenomena in the port, but explored the coast all the way to Pesaro and Fano, studying the configuration and the advantages of the neighboring harbors as he measured the depths of the sea in these ports and beaches. He gathered information on the former states of the port and the changes occurring from old fishermen and seamen, in order to compare them with the current state of the port. He learned some important facts from the harbor masters, who were in charge of maintenance, and from the individuals who had access to the official records relating to the port. The most important of the latter was Serafino Calindri, who had gathered many documents concerning the history of the port, and also many facts about the ports at the river mouths where siltation was evident. The publication of Calindri's observations about the port of Rimini had led the councilors to seek the advice of Ruđer Bošković, a distinguished expert in this field. Bošković had, thus, developed a systematic approach comprising various methods, which he applied with much attention (*diligenze usate*).

The same systematic approach can be seen in his logically structured report on the port, divided into three parts:

- (1) description of the former and the current conditions of the port and the river channel
- (2) analysis of the causes of the damage
- (3) proposal for remedial steps in the port and the river channel.

This was the model Bošković tested in Magnavacca, further developed in Rimini and applied again to the port of Savona in 1771.

32 Cf. "Proemio: Chiamata, arrivo, diligenze usate, elogio delle fatiche del Sig. Calindri," in BOSCOVICH, *Del Porto di Rimini memorie*, pp. 1-3.

33 Ruđer Bošković to Giovan Stefano Conti, Rimini, 13 October 1764, in Ruggiero Giuseppe BOSCOVICH, *Lettere a Giovan Stefano Conti*, pp. 168-170, on p. 168: ".. e rispondo in fretta, perche tutta questa mattina sono stato a scandagliare il porto ..."

DEL PORTO
DI RIMINI
MEMORIE
DEL PADRE
RUGGIERO GIUSEPPE
BOSCOVICH
DELLA COMPAGNIA DI GESU'.



IN PESARO, MDCCLXV.
~~~~~  
PRESSO DONNINO RICCI.  
CON LICENZA DE' SUPERIORI.

Figure 4. Bošković's evaluation of damage to the port of Rimini: the title page of the first edition. Boscovich, *Del porto di Rimini memorie* (Pesaro: Ricci, 1765).



Having studied the problem very carefully, Bošković wrote a report in which he disagreed with the prevailing views about the causes of the damage. Contrary to what the fishermen thought, he excluded the possibility that the replacement of the timber piles by solid ones could have resulted in the deterioration in the conditions of the port. He also ruled out the possibility that the direction of the channel might have had a destructive effect. In his opinion, the main threat to the port was the deposition of sandbars accumulated by the River Marecchia at the port entrance. The section of the report referring to the causes of the damage was supplemented by a tract on the application of the properties of the cycloid in the explanation of the motion of water in the port.<sup>34</sup>

Bošković ended the report with numerous instructions in case the configuration of the port remained unchanged, i.e. if the Marecchia continued to flow into the port for how to keep the entrance to the port clear, how to remove the sand that the Marecchia deposited at the entrance and how to reduce the scale of siltation at the mouth of the Marecchia. Finally, he concluded, the best solution would be if the Marecchia did not flow into the port. He advised the councilors of Rimini to act according to the saying *chi più spende, meno spende* (*he who spends more, spends less*).<sup>35</sup>

The approach used in this report is completely different from that in Bošković's scientific letter on the principles of hydrodynamics, which is the only entirely theoretical treatise among his works in the field of hydraulic engineering and hydrodynamics. In addition, *Lettera ... sulli principj* also differs, in terms of methodology, from Lecchi's basic idea of how to write a monograph on hydrostatics, although Bošković wrote it after having read Lecchi's text. Lecchi must have noticed this difference because he added the following remark to Bošković's *Lettera*:

"In the following article about stream channels in natural and artificial beds, I shall propose an easier and quicker method, though somewhat less exact, which yields the average velocity by means of various immersions of a ball. I opt for this method because it is more easily understood by those who are not acquainted with higher geometry, and if it is used with care, which will be discussed further on, it can also be considered safe in practice."<sup>36</sup>

34 Cf. the chapter "Se ne esclude la dirittura: che non ha qui luogo la teoria della cicloide," in BOSCOVICH, *Del Porto di Rimini memorie*, pp. 20-29.

35 Cf. BOSCOVICH, *Del Porto di Rimini memorie*, pp. 58, 66.

36 LECCHI, *Idrostatica*, p. 345: "Nel seguente Articolo io per le acque correnti negli alvei, proporrò appunto un metodo più facile, e spedito, benchè alquanto meno esatto, il quale coll' ajuto delle diverse immersioni della palla, ci dà la velocità media. Io fo scelta di questo metodo,

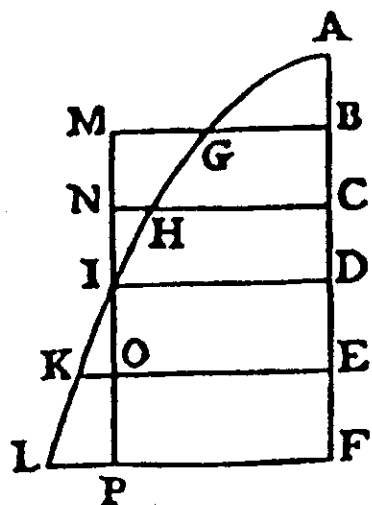


Figure 5. Determination of the average velocity of fluid flow: the quadrature of the surface under the continuous curve GIL of velocities. Boscovich, "Lettera ... sulli principj, su' quali si possano appoggiare le Regole pratiche per la misura dell' acque, ch' escono dalle aperture, e corrono per gli alvei," in Antonio Lecchi, *Idrostatica* (Milano: Marelli, 1765), p. 320.

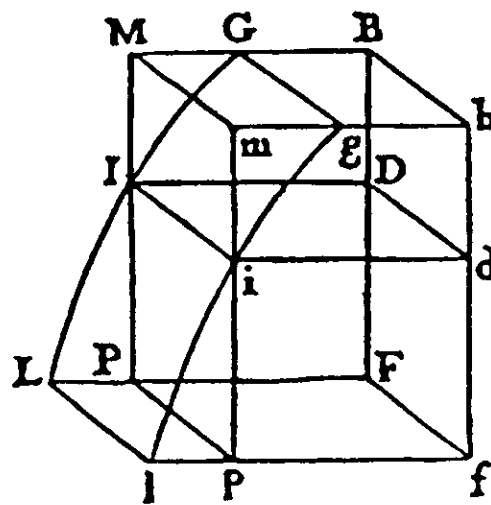


Figure 6. Determination of the average velocity of fluid flow through the section Bbff: cubature of the volume under the continuous surface GgIL of velocities. Boscovich, "Lettera ... sulli principj, su' quali si possano appoggiare le Regole pratiche per la misura dell' acque, ch' escono dalle aperture, e corrono per gli alvei," in Antonio Lecchi, *Idrostatica* (Milano: Marelli, 1765), p. 321.

In his letter to Lecchi, Bošković elaborated on the geometrical presentation of the average velocity of fluid flow: if every point of the perpendicular **BF**, which belongs to the cross-section of a channel or an outlet of the vessel **BbFF**, is assigned the absolute velocity of the fluid at that point, then the termini of these velocity vectors will form a continuous curve **GIL** of velocities (see Figures 5 and 6). Therefore, Bošković infers, "it is clear that the problem is reduced to the quadrature of the area under this curve."<sup>37</sup> His attitude towards the calculation of the area under the curve, which is the initial problem of integral calculus, reveals the attitude of a mathematician towards the choice of method. Bošković, who taught mathematics at the renewed University of Pavia in 1765, established that for different curves of velocities or different areas under the curves of velocities, the magnitude of fluid flow can always be represented in two ways: geometrically or by means of integral calculus.<sup>38</sup> He was even more direct when describing the general

perchè più ad intendersi anche da chi non è introdotto nella sublime Geometria; e quando si usi con le cautele, che riferirò, può dirsi sicuro ancora nella pratica;"

37 BOSCOVICH, "Lettera ... sulli principj," p. 321: "si vede chiaro, che il problema si riduce alla quadratura dell' area di essa curva;"

38 BOSCOVICH, "Lettera ... sulli principj," p. 324: "In essi casi ad ogni modo si può parimente rappresentare la quantità dell'acqua colla Geometria, o col calcolo sommatorio."

methods (*i metodi generali*) serving to bridge the gap between geometric construction and numerical values:

“First of all, when the nature of the curve is generally given, its area [= area under it] can sometimes be obtained by geometrical methods themselves, just as Archimedes found the quadrature of the parabola, but it is more frequently reached by means of integral calculus. This area can also be accurately obtained by a finite algebraic expression... When it is not possible to integrate the formula, it is often necessary to resort to approximation by means of series which, if strongly convergent, yield the requested value at once, without much tiresome numerical calculation. If the series converge weakly or even diverge, it is convenient to resort to other methods of approximation, one of them being *interpolation*, which is also used in case the nature of the curve is generally unknown so that the values of many ordinates corresponding to many points given on the axis may be obtained by direct observation or in some other way.”<sup>39</sup>

Bošković's outline of general methods included all the mathematical techniques of the time, as he explicitly specified when and under what conditions they should be applied: *integration* for integrable functions, *approximation* by an infinite convergent series for unintegrable functions, *interpolation* if the approximation of the function is made by a divergent series or if the function is given on a finite set. Though Bošković did not discuss it in detail in his *Lettera*, his choice of method was undoubtedly up-to-date if viewed from the perspective of 1765.

Illustrative of his persistent views is an event which took place in 1784, when Girolamo Ascanio Giustinian asked Bošković to review a paper on hydraulic engineering by an unknown author. Bošković considered the text to be a hostile attack on Lorgna and other mathematicians who were well-versed in hydraulic engineering. In his answer to Giustinian of 11 September 1784, he wrote that the mathematicians in question applied pure mathematics to hydraulic engineering (*in materia d'acque*) a great deal more

39 BOSCOVICH, “Lettera... sulli principj,” pp. 325–326: “In primo luogo, quando è data generalmente la natura della curva, si trova la sua area qualche volta anche co' soli metodi geometrici; come Archimede trovò già la quadratura della parabola; e più generalmente col calcolo integrale: la quale area alcuna volta si trova accuratamente con una espressione algebraica finita,... Più spesso accade che non potendosi integrare le formole, si adoperino le approssimazioni per via di serie, le quali, se sono assai convergenti, danno presto, e con poco travaglio di calcolo numerico il valore cercato: ma se convergono lentamente, o ancora divergono; conviene rivolgersi ad altri metodi di approssimazione, tra li quali vi è quello, che si chiama delle *Interpollazioni*, il quale serve ancora pel caso, in cui non sia cognita generalmente la natura della curva, ma si possano avere o per immediata osservazione, o in altro modo i valori di molte ordinate corrispondenti a molti punti dati dell' asse.” Emphasis by Bošković.

than the physical problems involved demanded, and since “the principles established by Lorgna were correct, far too recognized and confirmed in practice,” the reasons put forward by his opponent could not be accepted.<sup>40</sup> This episode at the end of Bošković’s life is further evidence of the importance he attributed to the relationship between hydraulic analysis and mathematical methods.

## Conclusion

As a young professor of mathematics at the Collegium Romanum, Bošković had already shown considerable interest in hydraulic engineering. When he was appointed to the chair of mathematics in Pavia, he proposed his own curriculum in *Piano scientifico* (1764), suggesting that lectures on hydraulics be introduced for the second-year students of mathematics, and a tutorial on navigation for the students who might take particular interest in the subject. In his relations with his fellow Jesuits, Bošković did not refrain from criticism, whether competing with Leonardo Ximenes (Firenze) or collaborating with Antonio Lecchi and Francesco Puccinelli.

His first expert analysis in hydraulic engineering concerned the navigable branch of the Tiber and was written at the request of Pope Benedict XIV. He was later asked to give his opinion on similar matters by the cities of Lucca, Rimini, Genoa, Perugia and Piacenza. The methodological approach he used in expert reports and theoretical papers on hydrodynamics is best exemplified in his report on the damage to the port of Rimini and in his scientific *Lettera* on the principles of hydrodynamics. Bošković used various methods in harbor expertise, as he himself wrote in the preface to his report on the port of Rimini: he measured and studied the currents in the port itself and along the coast, interviewed old fishermen and sailors and studied the documents and other written sources relating to the port. His theoretical essay on hydrodynamics shows how well acquainted he was with the mathematical techniques of his time.

<sup>40</sup> Ruđer Bošković to Girolamo Ascanio Giustinian, Bassano, 11 September 1784, in Rita TOLOMEO, “Ruggiero Giuseppe Boscovich a Bassano,” *Atti e memorie della Società Dalmata di storia patria* 13 (1988–1989), pp. 119–216, on pp. 172–173: “I principj stabiliti dal Lorgna sono, a mio giudizio sicuri, e sono in oggi troppo riconosciuti per veri anche in pratica ...”

## APPENDIX

### A Catalogue of Bošković's Manuscripts and Published Works on Hydraulic Engineering and Hydrodynamics

- 1.1. *Scrittura sú le cagioni, e rimedj de Danni seguiti nelle passonate di Fiumicino per l'Escrescenze degl'Anni 1750, e 1751.* Del P. Ruggiero Giuseppe Boscovich della Compagnia di Gesù, che contiene i sentimenti communi anche al P. Cristiforo Maire della medesima Compagnia. A copy of the manuscript in calligraphic form is kept in the Archivum Romanum SI, Roma, *Opera Nostrorum* 90/III., ff. 1-17.
- 1.2. Cf. Bošković's autograph with the same title, pp. 1-20, nn. 1-67, with an appendix "Mutazioni fatte." Ms. 39 in Branimir TRUHELKA, "Katalog rukopisa," in *Grada za poznavane života i rada R. Boškovića: Katalozi*, fasc. XV, f. 100.
- 1.3. See also *De'danni del Tevere sopra Porto Felice, e sotto il Ponte di Rustica.* A fair copy written in someone else's hand and signed by Bošković "Ruggiero Giuseppe Boscovich della Compagnia di Gesù," pp. [1]-[19], without pagination. Ms. 41 in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 100.
- 2.1. A collection of notes concerning Bošković's negotiations with the Florentine delegation, especially with the Florentine expert Leonardo Ximenes, held in Ripafratta from 9 September to 17 October 1756, in order to solve the controversy about the swamps near Lake Sesto in the border area between Lucca and Tuscany. The manuscript legacy, including Bošković's autographs, is housed in the Archivio di Stato, Lucca, *Offizio sopra i Paludi di Sesto*, 51. See the titles of all 23 papers in Gino ARRIGHI, "Ruggiero Giuseppe Boscovich e Lucca," in *Actes du Symposium international R. J. Bošković 1961* (Beograd / Zagreb / Ljubljana: Conseil des Académies RFPY, 1962), pp. 269-281, note 5, on pp. 270-271.
- 3.1. *Livellazioni fatte da Ripafratta fino al Lago per Serchio, e Ozzeri e Regio con varie altre misure prese a Ripafratta, e su per li ponti dell'Ozzeri, e Regio da' 23 Settembre 1756 a' 29 dello stesso mese. Determinazione della Steccaia*, pp. 1-16. Other material is also enclosed, including two drawings, one of them colored, size 20 x 27.5 cm. Bošković's autograph, Ms. 56 in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 104.
- 4.1. *Visita fatta con Sua Eminenza il Cardinale Buonaccorsi alle Paludi Pontine.* Dal P. Ruggiero Giuseppe Boscovich della Compagnia di Gesù. The diary was kept from January 19 to March 25, 1764, in one column, pp. 1-90, nn. 1-377, and a leaf with numerical data and sketches was added to it. Bošković's autograph, Ms. 49 in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 102.
- 4.2. Compare the transcription with the same title, without pagination, nn. 1-377, without appendices. Ms. 49' in TRUHELKA, "Katalog rukopisa," fasc. XV, ff. 102-103.
- 5.1. "Esame del Progetto de'Sigg. Manfredi, e Bertaglia in riguardo alle Paludi Pontine, e Porto di Terracina del Sig. Abate Ruggiero Giuseppe Boscovich, allora Professore di Matematica nell'Università di Roma de'PP. Gesuiti," in Leonardo XIMENES, *Raccolta delle perizie ed opuscoli idraulici ... alla quale si aggiungono le perizie di altri Professori che anno scritto sulle stesse materie*, Tomo I. (Firenze: Nella Stamperia di Pietro Allegrini alla Croce Rossa, 1785), pp. 75-115. It was supplemented by "Nota del Sig. Abate Ximenes alla pagina 89. nell'Esame del Sig. Abate Boscovich," pp. 115-116. In this collection, the reports concerning the Pontine Marshes were accompanied by a topographical map *Pianta Topografica delle Paludi Pontine ricavata da quella del Meyer, e del Sani*, which was made by A. Gio. Canocchi. Paduli Pontine Tavola I., 27 x 15. 2 cm. Historical Archives in Dubrovnik, R 709/1.

- 5.2. See Bošković's autograph *Dalla relazione del Bertaglia, e Manfredi per seccare le paludi*, pp. 1–9, probably the groundwork for "Esame." Ms. 53 in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 103.
- 6.1. *Del Porto di Rimini memorie*. Del Padre Ruggiero Giuseppe Boscovich della Compagnia di Gesù (Pesaro: Presso Donnino Ricci, 1765), 71 pages. Historical Archives in Dubrovnik, R 398.
- 6.2. Compare Bošković's autograph *Porto di Rimini*, pp. 1–47. Ms. 58 in TRUHELKA, "Katalog rukopisa," fasc. XV, ff. 105–106. See also the partial transcription of the same manuscript. Ms. 58' in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 106.
- 6.3. The second edition was published in *Raccolta di dissertazioni matematico-idrostatiche de' celebri PP. R. G. Boscovich, Jacquier, Le Seur, Pio Fantoni, A. Lecchi, F. M. Gaudio*, con note ed aggiunte di Serafino Calindri (Roma: Apud Bernabò e Lazzarini, 1769).
- 6.4. Ruggiero BOSCOVICH, "Del porto di Rimini," in *Opere idrauliche di Eustachio Zanotti ed alcuni opuscoli di Ruggiero Boscovich, e Leonardo Ximenes*, in *Raccolta d'autori italiani che trattano del moto dell'acque*, Tomo VII. (Firenze, 1823), pp. 345–409. Historical Archives in Dubrovnik, R 701.
- 7.1. *Voto per la verità del Padre Ruggiero Giuseppe Boscovich della Compagnia di Gesù, Lettore di Matematica nella Università di Pavia: Intorno agli effetti di tre Argini trasversali alzati sulle alluvioni della penisola delle Caselle del Sig. Marchese Francesco M. Lando verso il Po* (Piacenza: Nelle Stampe di Niccolò Orcesi, e Giuseppe Tedeschi, 1764).
- 8.1. "Lettera del P. Boscovich sulli principj, su' quali si possano appoggiare le Regole pratiche per la misura dell' acque, ch' escono dalle aperture, e corrono per gli alvei." in Antonio LECCHI, *Idrostatica esaminata ne' suoi principj e stabilita nelle sue regole della misura dell' acque correnti* (Milano: Nella Stamperia di Giuseppe Marelli, 1765), pp. 319–345. Historical Archives in Dubrovnik, R 622.
- 8.2. See the transcription of Bošković's letter, pp. [1]–[27], without pagination. Ms. 54 in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 103. The text is identified by the introductory sentence: "Vengo a soddisfare colla presente alla richiesta, che V. R. mi fa di quello, che io pensi sulli principj, e regole per la misura delle acque, ch'escono da' vasi, e corrono per gli alvei."
- 9.1. *Scrittura del P. Ruggiero Giuseppe Boscovich della Compagnia di Gesù sulli torrenti Caina, e Nistore da lui visitati a istanza de' Signori Delegati Apostolici pel nuovo regolamento ...*, pp. 1–28. *Ristretto del parere sulli danni cagionati dal fiume Caina, e loro rimedj del P. Ruggiero Giuseppe Boscovich della Compagnia di Gesù correlativo ad una sua più voluminosa scrittura*, pp. 1–3. The diary, pp. 1–6. Calculations of inclinations, p. 1. A contour map for the area between Ponte Mellino and Ponte Forcione, p. 1. Bošković's autograph. Ms. 56 in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 104.
- 10.1. *Sui danni del Porto di Savona loro cagioni e rimedi: Relazione ufficiale fatta nel 1771 dal P. Ruggiero Giuseppe Boscovich*, pubblicata per cura di Giuseppe A. Rocca (Savona: Tipografia Ligure, 1892), 62 pp. Off-print: "Dal giornale *Il Vero*." Historical Archives in Dubrovnik, O 3123–387.
- 10.2. Cf. the manuscript *Scrittura sulli danni del Porto di Savona, lor cagioni, e rimedj: del P. Ruggiero Boscovich della Compagnia di Gesù*, pp. 1–20, nn. 1–74, con disegno del Porto. *Compendio del risultato delle visite, e dell'idea concepita sulle cagioni, e rimedj de mali, che ha il Porto di Savona*, pp. 1–4, nn. 1–23. Ms. 35 in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 99.
- 11.1. *Memoria, e dubbj presentati al P. Boscovich Professore R. nelle Scuole Palatine in Milano nel 1771. appartenenti al Torrente Tidone nel Piacentino. Due lettere relative all'incumbenza datagli di esaminare tal questione. Parere di esso P. Boscovich firmato, e legalizzato da Notaro*. Ms. 24 in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 79.

- 12.1. *Relazione di un accesso fatto a'condotti delle Fontane di Perugia dal P. Ruggiero Giuseppe Boscovich della Compagnia di Gesù, e suo parere sul riattamento delle medesime.* Kept in the Archivio di Stato, Lucca, *Archivio Arnolfini*, 119. See Gino ARRIGHI, "Ruggiero Giuseppe Boscovich e Lucca," p. 273.
- 13.1. *Sullo sbocco dell'Adige in Mare 1773*, pp. 1–16. Bošković's autograph. Ms. 36 in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 99.
- 13.2. *Sullo sbocco dell'Adige in mare 10 Luglio 1773*, pp. 1–14, a transcription. Ms. 36' in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 99.
- 13.3. "Scrittura del P. Boscovich sullo sbocco dell'Adige in mare: 10 Luglio 1773," in *Memorie del Lorgna, dello Stratico e del Boscovich relative alla sistemazione dell'Adige e piano d'avviso del Lorgna per la sistemazione di Brenta* (Padova: Tipografia del Seminario, 1885), pp. 92 sqq.
- 14.1. *Risposta data da Parigi 6 Settembre 1774 alle richieste fattegli dalla Compagnia spedita alle Paludi Pontine.* Bošković's answer dated 6 September 1774 to the requests made by the maintenance team concerning the Pontine Marshes. Bošković's autograph, pp. 1–6. Ms. 48 in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 102.
- 15.1. *Regolamenti per la Compagnia da formarsi pel disseccamento delle Paludi Pontine stesi in Parigi.* Dall'Ab. Boscovich nel Dicembre del 1774. Bošković's autograph, pp. 1–11. Ms. 47 in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 101.
- 16.1. *Riflessioni dell'Ab. Boscovich sulla Relazione del Sig. Ab. Ximenes appartenente al progetto di un nuovo Ozzeri Lucchese*, pp. 1–28, nn. 1–68, with the following inscription on the cover: "Sull'progetto del Canal di Lucca in Gennaro 1781." Bošković's autograph. Ms. 43 in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 101.
- 16.2. "Riflessioni sulla relazione del Sig. Abate Ximenes appartenente al Progetto di un nuovo Ozzeri nello Stato Lucchese del Signore Abate Ruggiero Giuseppe Boscovich," in *Piano di Operazioni Idrauliche per ottenere la massima depressione del Lago di Sesto o sia di Bientina* (Lucca: Presso Francesco Bonsignori, 1782), pp. 173–205. It also includes "Copia di Lettera di Parigi in data del dì 8 Aprile 1781 del Sig. Abate Boscovich scritta al Sig. Gio. Attilio Arnolfini, da servire per Appendice alle sue Riflessioni sopra il Nuovo Ozzeri," pp. 202–205. The book includes the map *Mappa delle Campagne, Laghi, Paludi Lucchesi, e Toscane dall'Arno presso Montecchio, e S. Giovanni alla Vena fino al Littorale di Viareggio, coll'indicazione della Linea d'un Nuovo Canale, da nominarsi il Nuovo Ozzori*, which was drawn by Mich. Xav. Flosi, Tav. I., 52. 5 x 40 cm. Historical Archives in Dubrovnik, R 704.
- 16.3. "Riflessioni sulla relazione del Sig. Abate Ximenes appartenente al Progetto di un nuovo Ozzeri nello Stato Lucchese del Signore Abate Ruggiero Giuseppe Boscovich," in *Opere idrauliche di Eustachio Zanotti ed alcuni opuscoli di Ruggiero Boscovich, e Leonardo Ximenes*, in *Raccolta d'autori italiani che trattano del moto dell'acque*, Tomo VII. (Firenze, 1823), pp. 199–226. Historical Archives in Dubrovnik, R 701.
- 17.1. *Scrittura dell'Ab. Ruggiero Giuseppe Boscovich sulle difficoltà proposte da'Signori Interessati contro il Progetto del Nuovo Ozzeri.* The manuscript is kept in the Archivio di Stato, Lucca, *Deputazione sopra il Nuovo Ozzeri*, 5.
- 17.2. The paper is partially published (nn. 1–3, 43–46) in Gino ARRIGHI, "Ruggiero Giuseppe Boscovich e Lucca," pp. 277–280.
- 17.3. Bošković's autograph with the same title, pp. 1–19, nn. 1–46, with the title on the cover "Scrittura fatta a Ripoli sul Nuovo Ozzeri di Lucca," with the following contributions:  
 (1) Difficoltà della scrittura del Sig. D. Agostino Matteucci, nn. 1–4;  
 (2) Nella scrittura de'Signori Giovanni Francesco Mansi, e Nicolao Orsucci, nn. 1–2;  
 (3) Nella scrittura de'Signori Giuseppe Tucci, e Giuseppe Nicolao Orsucci, nn. 1–19;  
 (4) Nella scrittura del Signor Ferrante Cittadella, pp. 1–3. Ms. 44 in TRUHELKA, "Katalog rukopisa," fasc. XV, f. 101.

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